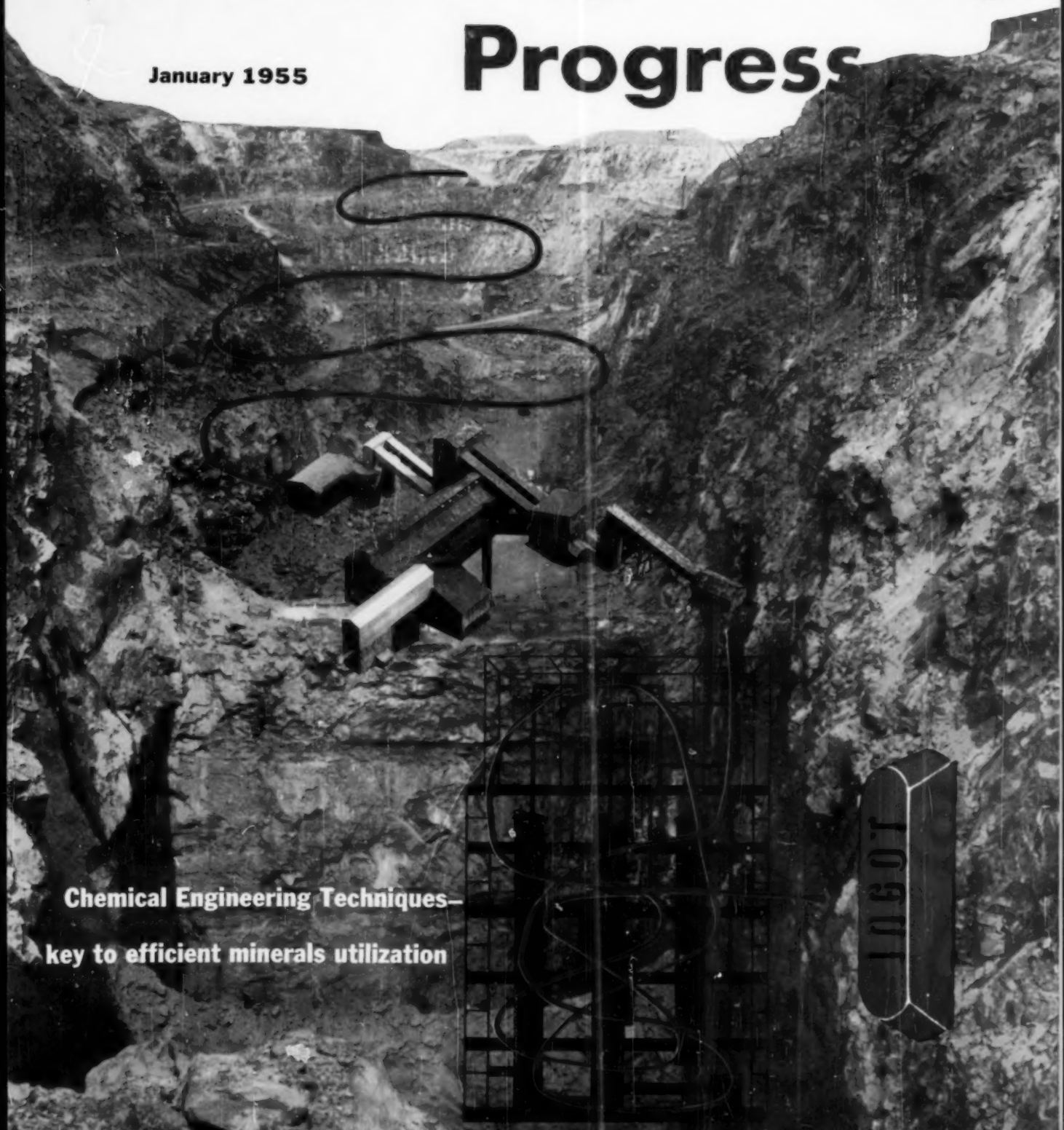
Chemical Engineering Progress

January 1955



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A Division of
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Chemical Engineering Progress

JANUARY, 1955 • Volume 51, No. 1

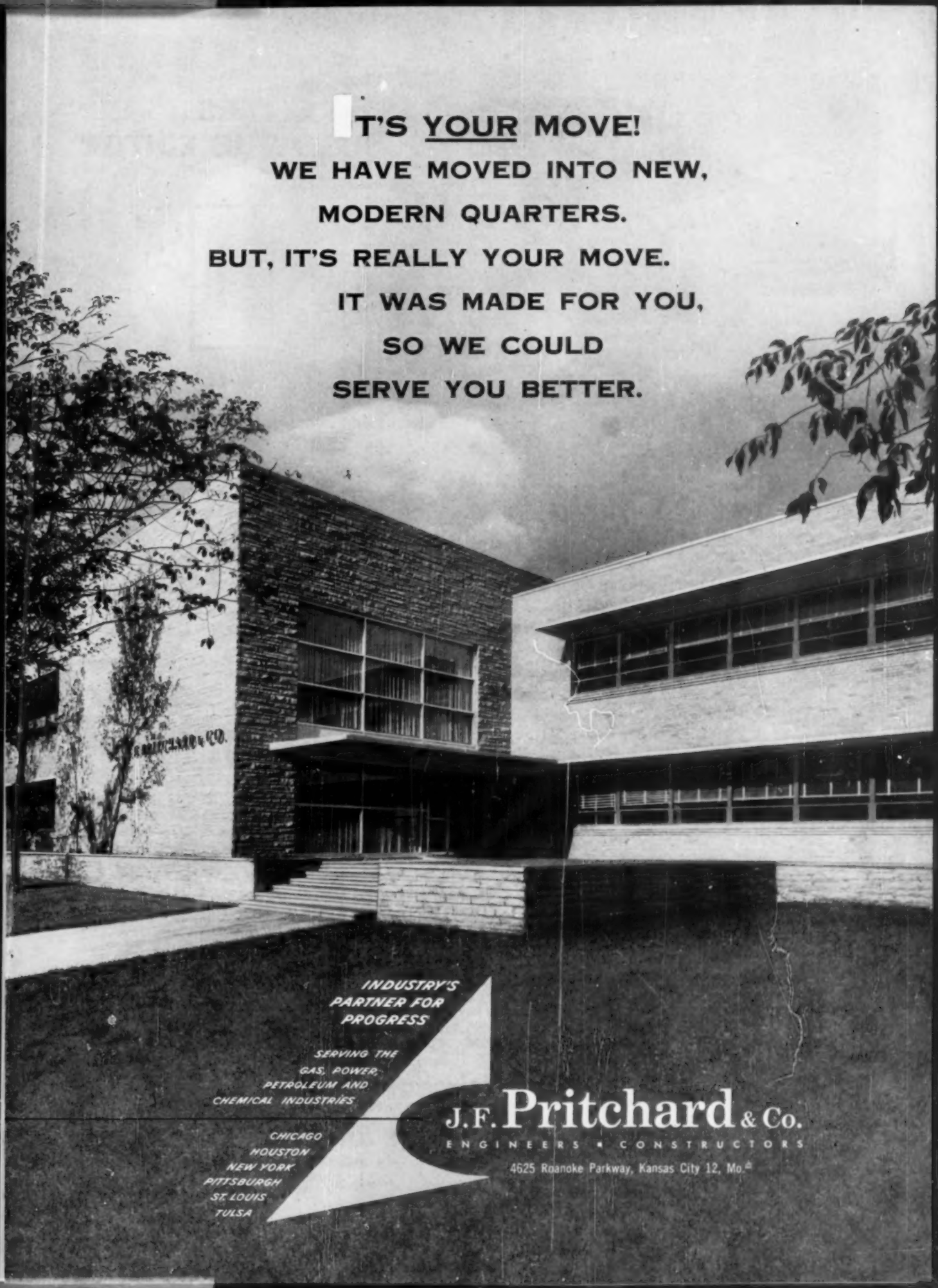
feature articles

this month's cover

Rock stripped from the mountain is crushed and its components physically drawn from one another. Some are dissolved and the resulting solution flows through the complex maze of a chemical separations plant. After reduction there is emergence, symbolically, of the ingot.

Published monthly by American Institute of Chemical Engineers at 15 North Seventh Street, Philadelphia 6, Pennsylvania, Editorial and Advertising Offices, 25 West 45th Street, New York 36, N. Y. Communications should be sent to the Editor. Statements and opinions in *Chemical Engineering Progress* are those of the contributors, and the American Institute of Chemical Engineers assumes no responsibility for them. Subscriptions: U. S. and possessions, one year $6.00; two years $10.00 (Applies to U. S. and possessions only.) Canada, $6.50; Pan American Union, $7.50; Other Foreign, $8.00. Single Copies of *Chemical Engineering Progress* older than one year cost $1.00 a copy; others are 75 cents. Entered as second class matter December 9, 1946, at the Post Office at Philadelphia, Pennsylvania, under Act of August 24, 1912.

Member of Audit Bureau of Circulations. *Chemical Engineering Progress* is indexed regularly by Engineering Index, Inc.


IT'S YOUR MOVE!
WE HAVE MOVED INTO NEW,
MODERN QUARTERS.
BUT, IT'S REALLY YOUR MOVE.
IT WAS MADE FOR YOU,
SO WE COULD
SERVE YOU BETTER.
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LETTERS TO THE EDITOR

A Reviewer Regrets . . .

Your November issue contained my review of C. C. D. A.'s book "Successful Commercial Chemical Development." This review was based on galley proofs which did not include the helpful summary table which follows the Foreword in the book as finally published.

I'm writing to call attention to this discrepancy in my review and also to note that important parts of the same table are used in Chapter 9, as well as in Chapters 10 through 13.

CARL A. SETTERSTROM

Brooklyn, N. Y.

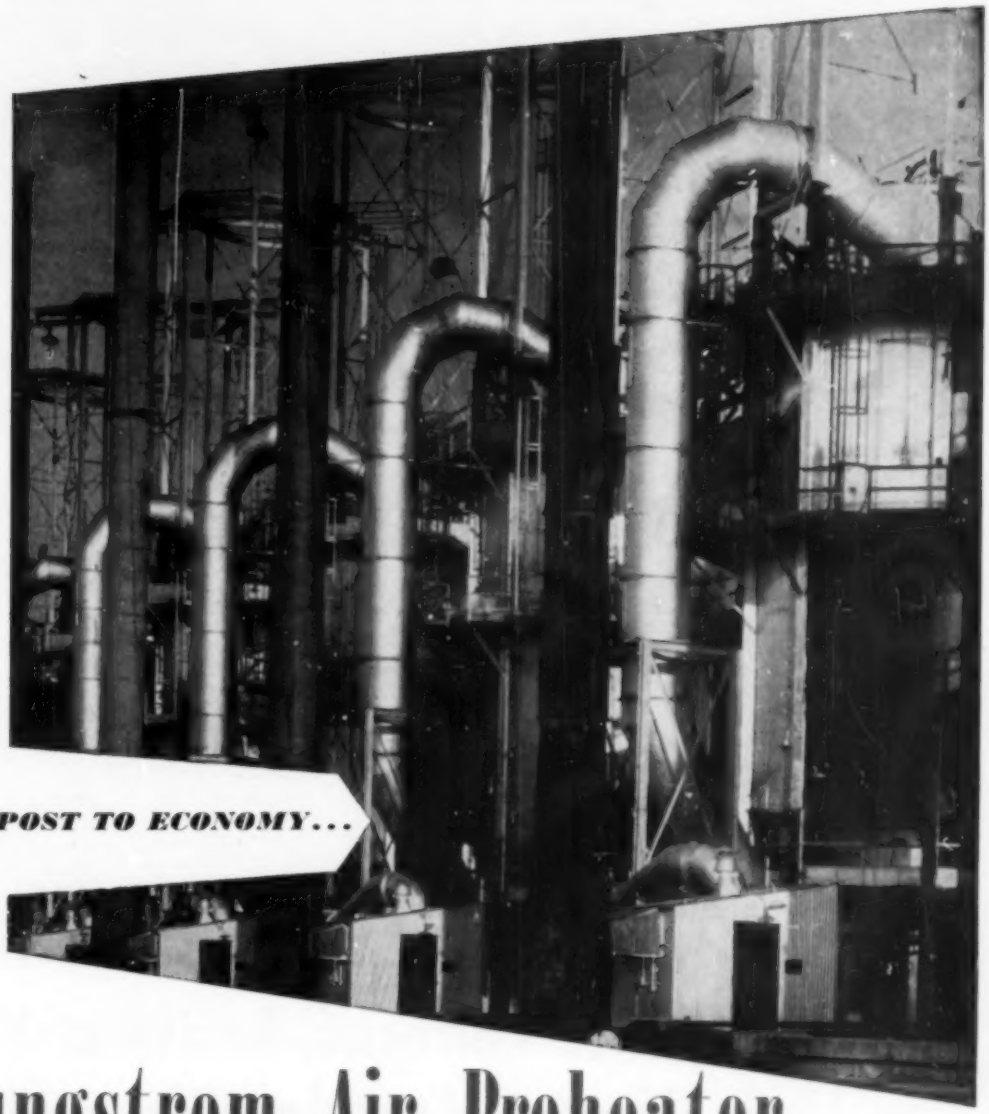
Another Forgotten Man?

Your editorial on "Who Is Responsible for the Instrumentation of Process Plants" (October issue) must have been delightful reading for those chemical engineers who work in the large plant category surveyed by you, and who therefore can avail themselves of the services of their no doubt ably and well staffed instrument departments. But this embraces only a fraction of your reader audience, and what about the plants of moderate size?

Meet the small and moderate plant category chemical engineer (SMPCChE), who is not only responsible for the instrumentation but also for process design, production control, research work and major pipe fitting jobs.

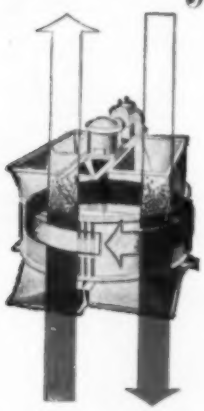
Unless he is lucky enough to work in a community within visiting distance of sales representatives, he frequently wishes he had taken that Instrumentation course back in college. His instrumentation lore is confined to advertisements and bulletins, strong on distances between mounting studs but, of necessity, short on the background information needed to form at least a nodding acquaintance with terms like automatic

(*Continued on page* 10)



GUIDEPOST TO ECONOMY...

The Ljungstrom Air Preheater



The Ljungstrom operates on the continuous regenerative counterflow principle. The heat transfer surfaces in the rotor act as heat accumulators. As the rotor revolves, the heat is transferred from the waste gases to the incoming cold air.

Every year, the process industries consume hundreds of millions of barrels of fuel. Refineries alone, for example, use up more than 200,000,000 barrels annually for processing crudes. This vast quantity of fuel represents probably the *greatest single item* in operating expense. If lower costs are to be realized, serious thought must be given to heat-conservation equipment.

The Ljungstrom Air Preheater offers the process industries a chance to save as much as *20% of the fuel needed for process work*. This fuel saving, plus the added benefit of increased production, makes the Ljungstrom an eminently practical piece of equipment to be considered wherever fuel is burned.

Check today to see how the Ljungstrom Air Preheater will pay for itself in just a few months — and give you impressive savings for years to come. Call or write The Air Preheater Corporation for full details.

Wherever You Burn Fuel, You Need Ljungstrom

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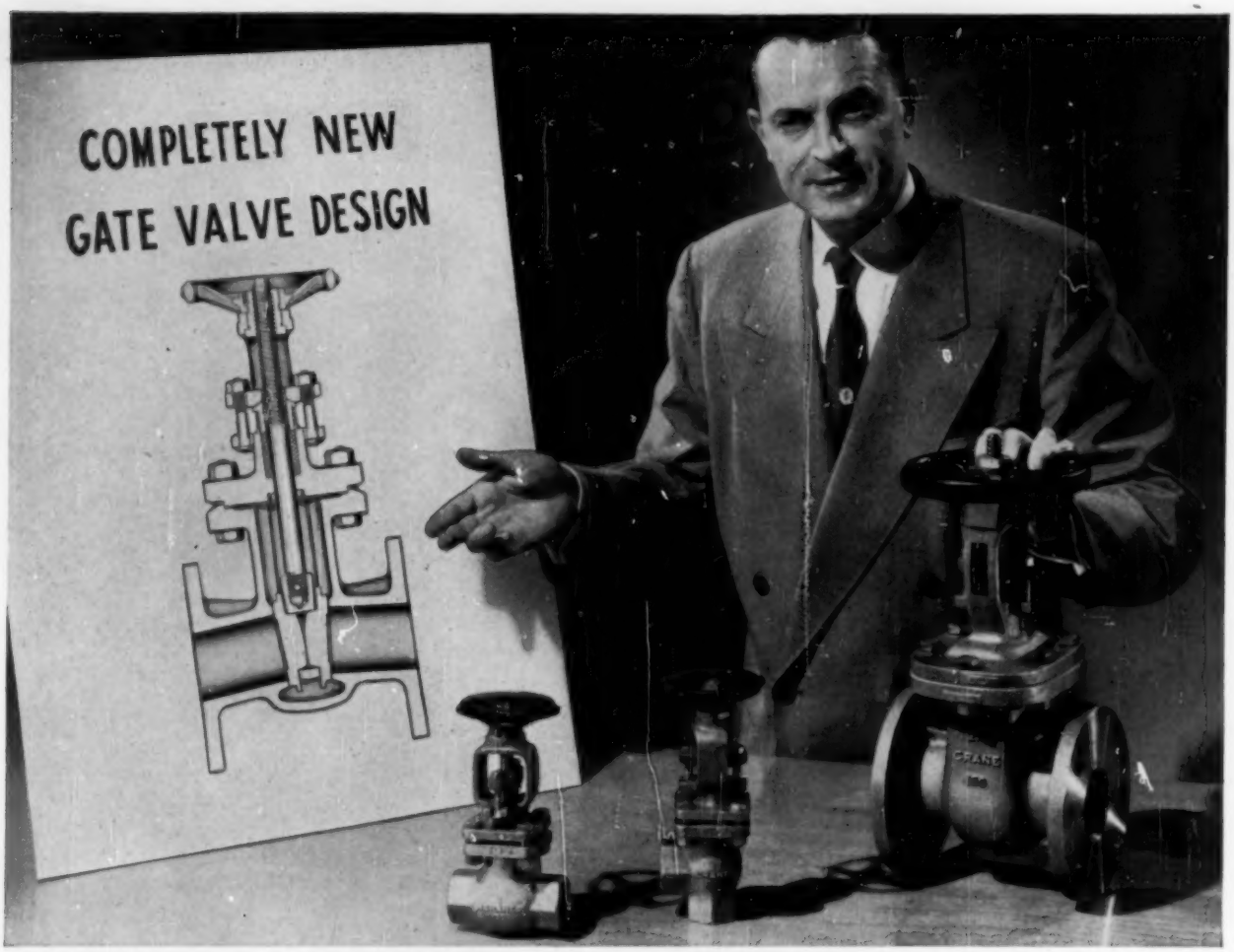


New CRANE Corrosion-Resistant Valves in 18-8 SMo and Craneloy 20

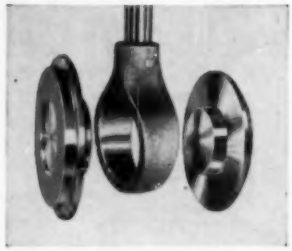
Gate, Globe and Angle Patterns

Few valves for process industries have ever received the quality treatment given this new Crane line.

Note, for instance, the unique yet simple split-wedge disc construction in the gate valves. Those dual identical discs are free to rotate in their holder—the most effective design for resisting galling. The trunnion shape at the back of each disc assures even distribution of closing forces. You couldn't buckle them if you tried.

The globe and angle valves give equally outstanding control of corrosive fluids. A new type disc-stem connection, with minimum clearances, practically eliminates vibration. By placing seating load closer to seats, it provides easier, more accurate closure.

Throughout, these valves are built for better service in your choice of Crane 18-8 SMo Stainless Steel or Craneloy 20. Both lines come with screwed or flanged ends. Full information given in circular AD 2059—available from your Crane Representative or on request to address below.



New split-wedge disc in gate valves combines the benefits of free rotation with uniform seat load pressure.

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LETTERS TO THE EDITOR

(*Continued from page* 6)

reset response, frequency response, derivative action, servo techniques.

The instrument makers should not be asked to do the entire job of information dispensation by themselves—it is my belief that the chemical engineering literature has a definite responsibility in keeping the profession up-to-date on instrumentation developments and research.

A series of papers on Process Instrumentation Fundamentals and Theory, and I stress Fundamentals and Theory, would most assuredly fill a large gap now existing. I sincerely hope that the editors of *Chemical Engineering Progress*, having recognized this need in the cited editorial, will consider the merits of such a series and come through in the manner commensurate with the importance of the subject to the small and moderate plant category chemical engineer.

GEORGE K. KLAUSNER
Stamford, Conn.

Engineers Can Write Better

Have read with interest the series * * * Dr. Ticky is to be commended for their excellence.

A. L. BABB
Assistant Professor
University of Washington

NOTE: The series "Engineers Can Write Better" is now available in reprints at 50 cents a copy.—EDITOR.

Censorship—A Misnomer

. . . I should like to break a lance on the hide of that dragon labeled "atomic energy censorship." . . . There is a deeply grounded misconception that the Atomic Energy Commission sits guard over all its information and snaps viciously at anyone who seeks to pull the most inconsequent piece out of the pile. Nothing could bear less resemblance to the actual facts.

While weapon data are, of course, "restricted" by *law*, the commission has wide latitude as to other data which it may declassify and release. There are a number of able people engaged in doing nothing else than reviewing and declassifying. We publish, bimonthly, a book of abstracts of scientific papers on the whole spectrum of the physical sciences, and these papers and reports now total many thousands. . . .

(*Continued on page* 14)

YORK Technical Literature

1 Yorkmesh DeMisters, Entrainment Separators and Mist Eliminators

A bulletin describing the clean separation between liquid and vapor in all types of process vessels by means of Yorkmesh DeMisters. Information covers construction, types, applications, engineering data and installation instructions for improving the performance of vacuum towers, distillation equipment, gas absorbers, flash drums, knock-out drums, scrubbers, and evaporators through the use of wire mesh entrainment separators and mist eliminators.

2 Solvent Extraction

A bulletin presenting principles of operation, typical applications and engineering data on standard laboratory and pilot plant York-Scheibel multi-stage extraction units which are highly efficient and practical for both simple counter current and fractional liquid extraction.

3 "Performance of Wire Mesh DeMisters" by: Otto H. York

Reprint of paper presented before A. I. Ch. E. describing the performance of wire mesh demisters. Presents case histories from the chemical, petroleum and petrochemical industries which show how wire mesh demisters, are being used to eliminate overhead losses and increase the quality of the overhead product, while permitting operation at vapor velocities which would otherwise be excessive.

4 Bulletin 16 "Clean Separation with Yorkmesh DeMisters"

Bulletin 16 provides a detailed technical explanation with photos and schematic diagrams of the construction, types and applications of wire mesh demisters used to insure clean separation between liquids and vapors in vacuum towers, distillation equipment, gas absorbers, scrubbers, evaporators, knock-out drums and steam drums. Also included in this bulletin is a discussion of the York-Scheibel liquid-liquid Multi-Stage extraction column which is highly efficient and practical for both simple counter current and fractional liquid extraction.

5 Case Study 1001 "Entrainment Elimination Gives 31% Capacity Increase"

Detail case study showing how the installation of a stainless steel wire mesh section in an asphalt vacuum still at the Sinclair, Wyoming refinery of Sinclair Refining Company stopped entrainment and increased capacity. The account describes how the wire mesh installation was made and includes complete data on operating conditions before and after installation.

6 Case Study 1002 "Catalyst Poisoning Reduced 90%"

Case Study 1002 shows how the installation of a wire mesh demister pad in a vacuum tower supplying a substantial portion of the charge stock to several cracking units at General Petroleum Corp.'s Torrence refinery resulted in a 90% reduction in catalyst poisoning. Also included is a detailed description of tower operating conditions, the method of wiremesh installation and a table comparing metals content before and after the installation was made.

7 Case Study 1003 "Yorkmesh DeMister Eliminates Caustic Spray"

This case story contains reproductions of the initial correspondence, recommendations, order and service history exchanged through the mails by Otto H. York Co., Inc. and process engineers at a chemical plant troubled with a serious air pollution problem caused by the fine caustic spray rising from the open top of a scrubbing tower when operated at a steam rate of 3000#/hr. The correspondence reveals how a 6" demister section recommended by York completely eliminated the objectionable caustic spray.

8 Case Study 1004 "Vacuum Tower Capacity Increased 35%."

This case history shows how the installation of stainless steel wire mesh sections in two vacuum asphalt towers at Marcus Hook, Pa., refinery of Sinclair Refining Co. increased feed capacity 30-35% while maintaining gas-oil quality. Included in the account is a complete description of vacuum tower operation, a table of operating conditions and a comparison of operations before and after the demister installation. Also included is a diagram of the vacuum tower indicating the position of the wire mesh filter and the relative positions of the internal elements.

9 Case Studies 1005 and 1006 "Yorkmesh DeMisters Cut Compressor Maintenance"

Two case history accounts tell, respectively, how a monel wire mesh demister was installed in the compressor suction drum of a deasphalting unit at a Gulf Coast Refinery to reduce high maintenance costs on propane compressors; and how installation of a monel wire mesh demister pad in the compressor suction line of the catalytic cracking unit at a Midwest Refinery completely stopped the excessive maintenance which resulted from dilution of valve lubricants by liquids entrained in the gas stream.

10 "Calculation of Liquid-Liquid Extraction Processes" by: Edward G. Scheibel, Hoffmann-LaRoche, Inc.

Twelve page illustrated booklet with diagrams, charts and graphs, primarily concerned with coordinating existing information and presenting the simplest and most direct methods for the study and design of liquid-liquid extraction processes.

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NOTED AND QUOTED

(*Continued from page* 10)

I am sure we are agreed that the ultimate survival of America is dependent on intellectual vigor and on spiritual deep rooting—not on specific devices which are always for the moment. The atom has no ethics of its own any more than it has politics. The future of the scientists' America, and yours and mine, lies fundamentally with education—that which is taught to the young in our schools—that which is taught throughout life in the media of general communication by the contemporary writers. Fundamental are respect and zeal for scholarship, a lively reward for moral values, and a love of truth. And of these the last is, of course, the greatest.

Lewis L. Strauss
Address before National Association of Science Writers, A.C.S. Meeting

Time Resolves Doubts

We ought to remember that the now flourishing science of biochemistry was once distrusted by chemists as well as physiologists.

E. D. Adrian
Science

Irradiation and the Human Being

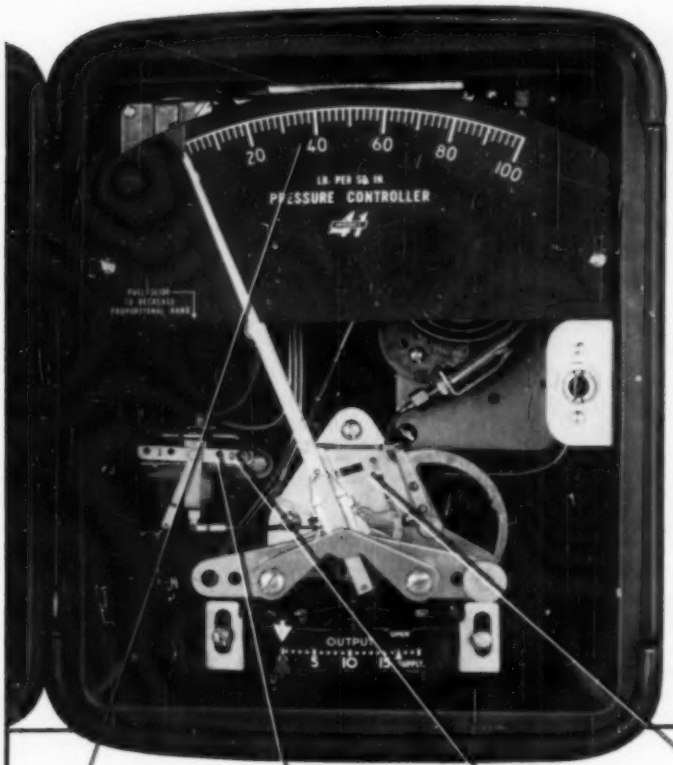
It follows . . . that any large-scale increase in the amount of irradiation to which human populations are subjected is a serious matter. Even though we cannot say that a given amount of irradiation will have a quantitatively specified effect, we can say that it will have some effect. The probability of an effect on the germ cells of any one individual may be very low; but when many millions of people are being exposed, it becomes certain that some of them will be affected. There is no possible escape from the conclusion that the bombs already exploded will ultimately result in the production of numerous defective individuals—if the human species itself survives for many generations. And every new bomb exploded, since its radioactive products are widely dispersed over the earth, will result in an increase in this ultimate harvest of defective individuals. Some such defectives would be present if the bombs had never been invented; the point is that the number due to the bombs will be added to this irreducible minimum.

A. H. Sturtevant
Science

(*Marginal Notes on page* 18)

Now!
An even **BETTER** Controller for simple processes!

...the improved Foxboro M/41A Indicating Controller



Here's the Foxboro Controller that proved itself in thousands of successful applications throughout industry! Now, with brand new design features, it's better than ever.

The M/41A Controller offers a new, snappy on-off action, or smooth proportional control action easily adjustable from .25% to 25%. It employs the famous M/40 controller movement — free from backlash, lost motion, and friction. This is a rugged, low-cost, compact controller using standard M/40 parts *throughout* . . . easy to get at . . . easy to service.

For control of simple processes—temperature, pressure, liquid level, or humidity — it will pay you to investigate the convenience and the precise, reliable performance of the Foxboro M/41A Indicating Controller. Write for Bulletin 5A-13.

New Design Features

- Longer Scale — 5" effective length.
- Snappy "On-Off" Control Action on measurement change of only ⅛ of 1% scale.
- Alternate Proportional Action adjustable from ¼ of 1% to 25%.
- "Permaligned" Precision Controller Movement — Exclusive Self-Aligning Ball-Linkage—Non-Backlash Vernier Index Drive
- Simple Rugged Construction—All Parts Easily Accessible

THE FOXBORO COMPANY, 931 NEPONSET AVE., FOXBORO, MASS., U.S.A.

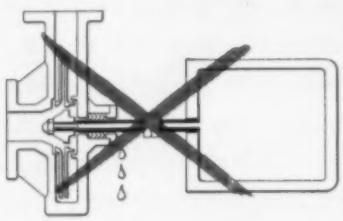
FOXBORO REG. U. S. PAT. OFF. **INDICATING CONTROLLERS**

FACTORIES IN THE UNITED STATES, CANADA, AND ENGLAND

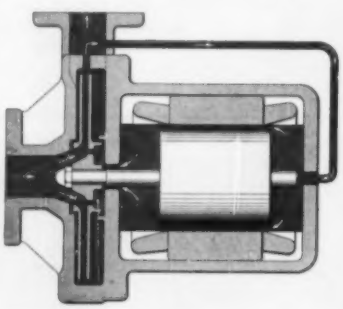
"CANNED ROTOR" PUMPS PAY OFF IN LOW UPKEEP COSTS, NO FLUID LOSSES

UNIQUE CHEMPUMP DESIGN SAVES TRICHLORETHYLENE USER $45 A DAY

Philadelphia, Pa. Officials of a large electrical switchgear manufacturer recently stated that $45 per day savings of trichlorethylene resulted from installing a Model CF Chempump on a distillation-type degreaser. Fluid losses with the ordinary centrifugal previously installed averaged 25 gallons a day. "On top of this," they stated, "we had to repack the pump every two days. We'd tried all kinds of packing, some of them very expensive—but without luck. Since installing the Chempump, we haven't lost a drop of solvent, and there has been absolutely no maintenance."



Design secret of the Chempump lies in combined construction of pump and motor, which eliminates seals, stuffing boxes, lubrication, long external shafts, etc. The Chempump allows pumped fluid to enter rotor chamber; a corrosion resistant liner isolates stator windings. Chempumps are available in sizes from 1/8 to 7 1/2 horsepower, and in a wide variety of construction materials.



NUCLEAR SERVICE REQUIREMENTS SPUR LEAK-PROOF PUMP PRODUCTION

Less than two years ago, only one company in the country was producing and marketing a canned-rotor pump. Today, spurred on by the atomic energy program, half a dozen firms are at work on models for atomic-powered submarines, nuclear energy central stations, even atomic-powered aircraft.

To the man in the chemical process industries, all this is good news, because canned-rotor pumps can't leak. They require no shaft seals or stuffing boxes, maintenance is practically nonexistent. And leakage losses, high maintenance costs are two of the biggest headaches centrifugal pump users face.

H. T. White and D. P. Litzenberg (left), developers of the first practical seal-less "canned-rotor" pump. On the desk are plans for an extreme-pressure, extreme-temperature design.

Canned-rotor pumps came about through the efforts of two young Philadelphia engineers, now officers and directors of the Chempump Corporation. Working on principles developed before World War II, they did further research and engineering, and in 1947 began production of a seal-less, canned-rotor pump.

Even while tooling up for production of this first model, the two designers were planning variations for specific applications in the chemical process industries. Pumps were built to handle extreme temperatures and pressures as well as a variety of corrosive fluids. The pumping requirements of chemical processors were carefully studied, and steps taken toward standardization of designs to meet those requirements.

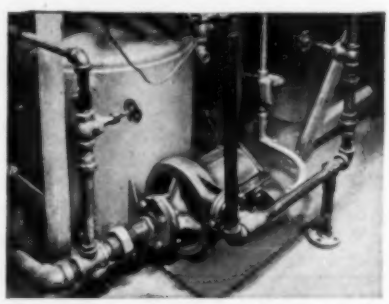
1952 saw the formation of the Chempump Corporation to build canned pumps for the chemical process industries. Experience gained from nearly 15 years of laboratory and field testing went into the design and production of products offered by this corporation. First in the field of canned-rotor pumps, Chempump is also first with pumps tailored specifically to the chemical processing industry.

PUMP SERVICE POLICY ENDS MAINTENANCE PROBLEMS

To reduce process downtime, many plants purchase a spare pump for every two, three, or five pumps installed, depending on circumstances. We feel this is a good policy, since downtime is limited to the time required to install a spare.

But what about repairing the faulty pump? Are proper spare parts on hand? How about maintenance department scheduling? The answer to these and other problems is the Chempump Service Policy. Any Chempump, damaged or inoperative for any reason—including improper pump application—will be repaired at the factory and returned to the customer with a new pump warranty. The pump is completely rebuilt, inspected and tested by factory experts . . . and the cost is moderate.

This service policy stops repair headaches, cuts spare parts inventory, and in effect, places a new pump on your shelves in short order.



Chempump handling condensate under extreme vacuum for large Eastern chemical manufacturer. Air contamination would render system inoperative.

Chempump First in the Field

CHEMPUMP CORPORATION
1379 EAST MERMAID LANE • PHILADELPHIA 18, PA.

MARGINAL NOTES

Chemical Business Handbook, John H. Perry, Editor in Chief, wtih a staff of 123 specialists. McGraw-Hill Book Co., New York (1954), 1,942 pages, $17.00.

Jack Perry, editor in chief of the "Chemical Business Handbook," and a long-time friend, died a year, almost to the day, before this review was begun. Jack is probably best known for his other handbook on chemical engineering, but the present offering may become just as popular. Certainly it is as painstakingly done and it too fills a gap in the chemical literature. Students coming into industry rely on Perry's "Chemical Engineers' Handbook" to familiarize themselves with obscure or unknown procedures. Now chemical engineers as they graduate into management have another voluminous guide to help them through unfamiliar first steps.

Briefly, this new volume describes in considerable detail the "unit operations" of the business side of the chemical industry—though its usefulness is by no means limited to this one field as it expounds principles well adapted to all business. For the sake of completeness here are the titles of the chapters: Business Finance; Management and Control by Cost Accounting and Planning; Commercial Chemical Development; Research; Market Research; Market Research Data and Sources of Information; Industrial Purchasing; Production; Traffic and Transporation; Sales; Industrial Advertising; Credits and Collections; Personnel Management; Public Relations; Business Law; Patents and Patent Law; Industrial Toxicology; Insurance and Loss Prevention; Reports and Report Writing; Business Mathematics. Each chapter is of uniformly good quality and each was written by a well-known expert in the field.

It is impossible for any reviewer to read thoroughly all the chapters—so inclusive a work is it. However, the last chapter, Business Mathematics, proved to be this reviewer's favorite. It is not, as might be expected, a treatise on percentage, but rather it is an exposition on graphical presentation and on the collection of graphs and charts. The illustration of methods of presenting data is one of the best to be found in one continuous run of pages.

It is to be regretted that Perry died before he could witness the success this book is certain to have. It and the

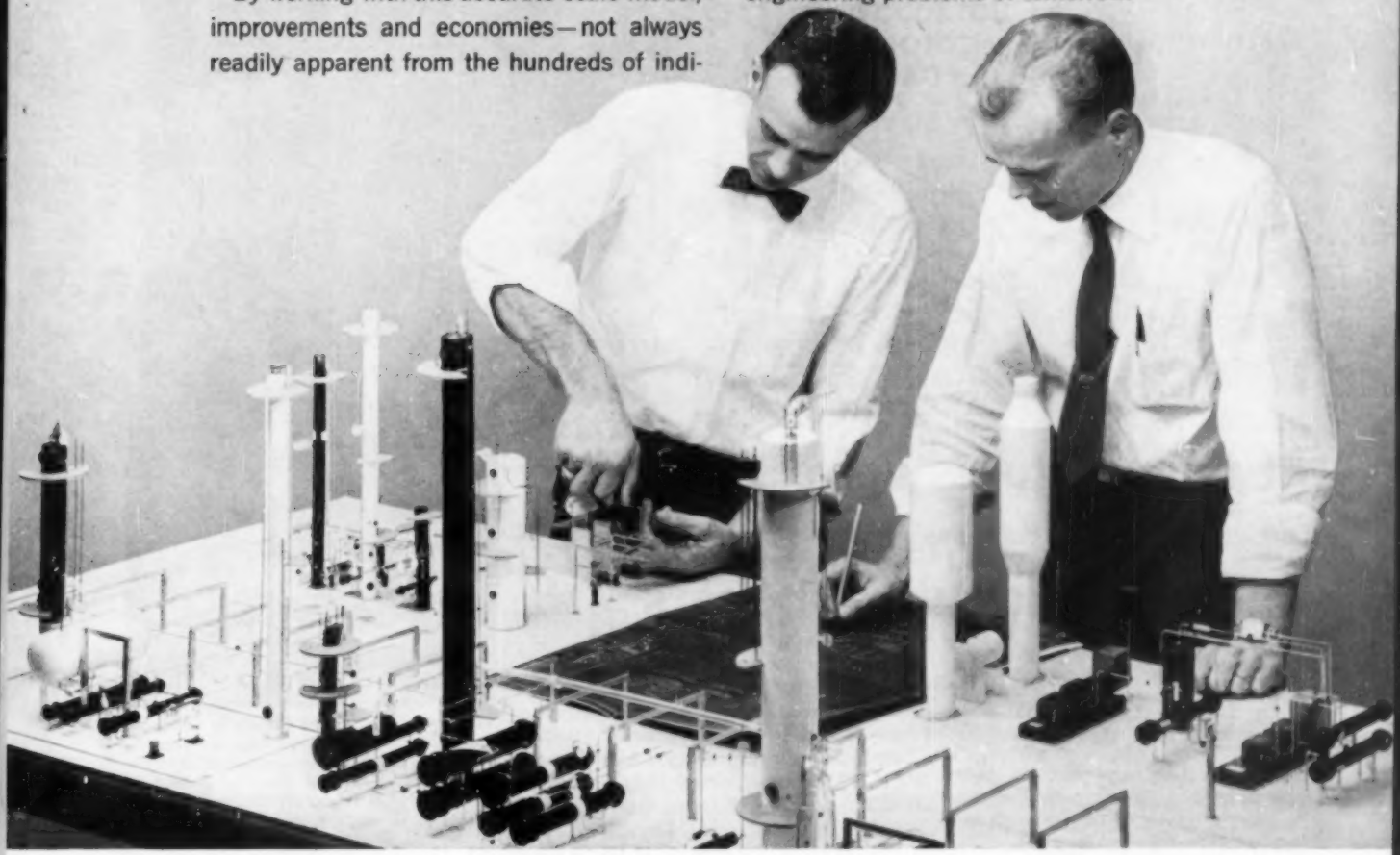
(*Continued on page 22*)

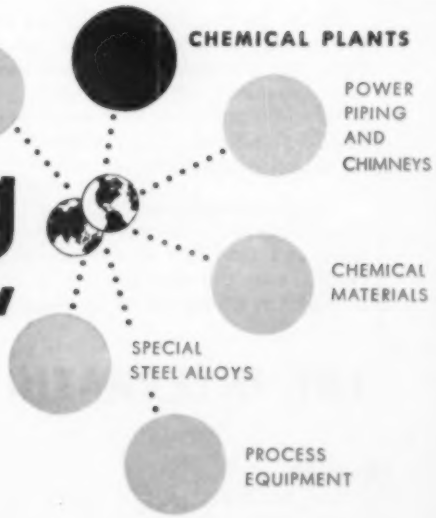
Three-Dimensional Blueprint

This is a very special-purpose model . . . of a new type petrochemical plant now being process engineered and designed by The M. W. Kellogg Company for a major oil company. Built as the engineering progresses, it provides an easy-to-grasp, three-dimensional picture of the miles of complex processing piping . . . the largest and most complicated phase of the construction.

By working with this accurate scale model, improvements and economies—not always readily apparent from the hundreds of individual working drawings of the pipe layout—can be quickly spotted and executed before construction is under way.

If you are considering an investment in petrochemicals, The M. W. Kellogg Company—world's leading designer and builder of petroleum refineries and other complicated processing plants—welcomes the opportunity to show you how it can solve your engineering problems of tomorrow.





M.W. Kellogg

ENGINEERING FOR TOMORROW

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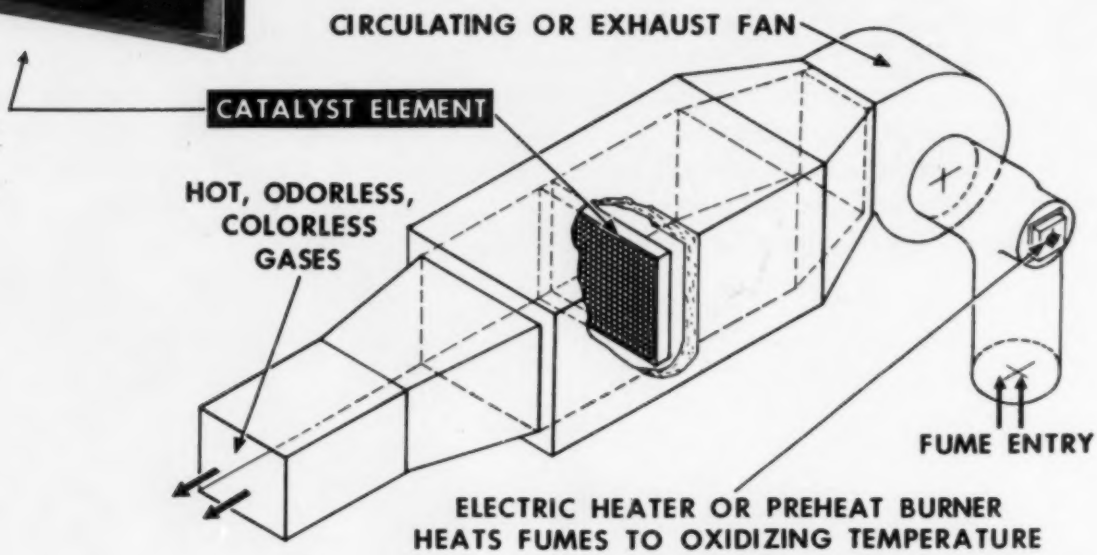
Basic Elements of Fume Combustion System for eliminating odorous, poisonous, explosive or flammable fumes from industrial processes. The Catalytic Combustion Corp., Detroit, Mich., produces and installs systems that furnish useful heat for many operations . . . while routing smog, smells and noxious gases.



At temperatures up to 1500°F

Catalytic Combustion Units Using Nickel-Chromium Alloys

Operate Efficiently for Years

Scores of plant operators now liberate and use heat energy that, heretofore, went to waste . . .

And by the same means, these operators control air pollution and convert noxious or explosive fumes into odor-free harmless gases.

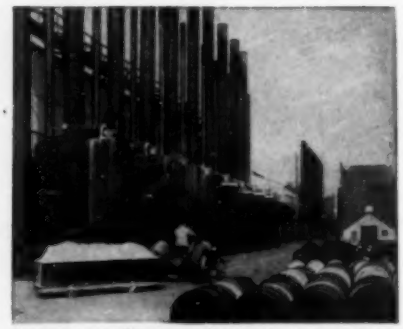
How? By catalytic oxidation on the industrial level. Thanks to a Catalytic Combustion Corporation development which utilizes the catalytic action of platinum and the heat-and-corrosion resistance of nickel-chromium alloys.

The drawing shows fundamentals of a catalytic fume combustion system, and the photograph shows a typical catalyst element, 18" x 24" x 2⅝", weighing about 30 pounds.

The latter comprises a frame of 18-8 chromium-nickel stainless steel, and 16-mesh screen of 60-16 nickel-chromium alloy (ACI Type "HW"), containing mat of this alloy in the form of ribbon . . . two miles of it . . . 1/16" wide. Deposited on this mat is the catalytic medium, vital metallic platinum.

Screens and mat of the 60-16 nickel-chromium alloy resist both heat and corrosion to an extent that assures long life and efficiency at temperatures up to 1500°F. Moreover, thermal expansivity of the alloy is close enough to that of platinum to prevent spalling or flaking of the catalyst.

Hourly, the 2-mile alloy ribbon mat with its catalytic agent can handle up to 3000 pounds of most gases, and liberate heat at rates up to 800,000 B.T.U.



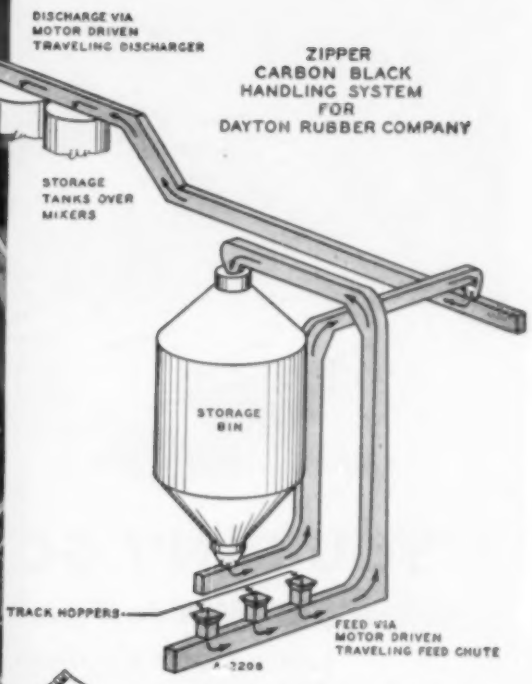
Large Installation of Catalytic Combustion Units . . . used to decompose irritating exhaust gases from production of phthalic anhydride at Detroit plant of Reichhold Chemicals Co. It comprises these two batteries of 10 units each, and eight similar units, not shown. Each incinerator processes 1200 cu. ft. of gas per minute, 24 hours daily. Ten initially installed in 1949 have now given more than 30,000 hours' service with no catalyst replacement.

Nickel alloys may help you, too, improve your products or equipment. Whenever you face a metal problem, send us the details for our suggestions.

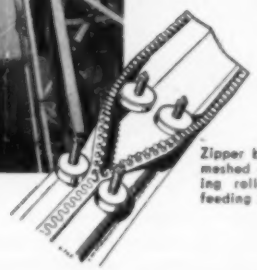
INCO

THE INTERNATIONAL NICKEL COMPANY, INC. 67 Wall Street New York 5, N.Y.

General view of S-A Zipper Conveyor-Elevator System for handling carbon black. Since the Zipper units operate in the open, they are protected from the weather by steel casings.



Sketch illustrates flow of carbon black through storage to processing via three ZIPPER belt conveyor-elevators. Note unit feeding from track hoppers which operates in two planes.



Zipper belt teeth are automatically spread, meshed and locked by means of ball bearing rollers as the belt travels past the feeding station.

Push Buttons Route Carbon Black Through Dust-Tight Zipper Distributing System

Remote control plus complete mechanization keynotes this conveying and storage system at the Dayton Rubber Company's Dayton, Ohio plant. Push buttons replace bag handlers — a single operator at a centralized control panel directs the 7-ton-per-hour flow of carbon black from hopper bottom rail cars, through storage, reclaiming and delivery to mixers in the plant.

Besides eliminating the excessive cost of handling the carbon black in bags, the system has greatly reduced degradation of the pelletized black and has practically done away with dust.

Incoming cars are spotted over the Zipper storage conveyor, which feeds from each one of the three track hoppers progressively selected at the control panel. At the 8-compartment storage bin, a motor driven swivel spout directs the flow of black to the proper compartment. In reclaiming, from storage, a Zipper Conveyor-Elevator discharges to a 238-foot Zipper that provides selective filling of the mixer storage bins.

If you have a dust or degradation problem, find out how much an S-A Zipper System offers you. Send for full data now.

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Sealmaster Division	A complete line of industrial ball bearing units available in both standard and special housings.

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Please send us Bulletin No. 349 on ZIPPER Conveyors

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Company_____

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City_____ Zone____ State_____

MARGINAL NOTES

(*Continued on page 28*)

earlier handbook are a monument to his integrity, knowledge, and industry and will keep his memory alive for many years to come.

FJVA

Symposium on Report Writing

The Technical Report. Edited by B. H. Weil. Reinhold Publishing Corp., New York (1954), xii + 485 pages $12.00.

Reviewed by D. H. Killeffer, Consultant, Tuckahoe, N. Y.

This valuable book deals with the mechanics of preparing and circulating a technical report. It does this clearly and effectively by bringing to bear on the subject the experiences and views of twenty-three authors all of whom can properly claim expertness in the matter treated. A foreword by the president of the Georgia Institute of Technology, Blake R. VanLeer, emphasizes the growing significance of technical reporting in its various phases as a vital function that engineers must perform in properly fulfilling their function in today's complicated society. The papers following the foreword analyze the different parts of the preparation, processing, and use of technical reports in a thoroughly professional manner. All the various modern techniques employed are examined and evaluated. The material presented has the important advantage of having previously formed a symposium presented on the subject and thus of receiving competent criticism before the editor undertook the useful task of working it into a unified volume. The editing is competently done and the result is a valuable book.

Statistical Analysis in Chemistry and the Chemical Industry. C. A. Bennett and N. L. Franklin, John Wiley & Sons, New York (1954), 724 pages, $8.00.

Reviewed by Cuthbert Daniel, Engineering Statistician, New York.

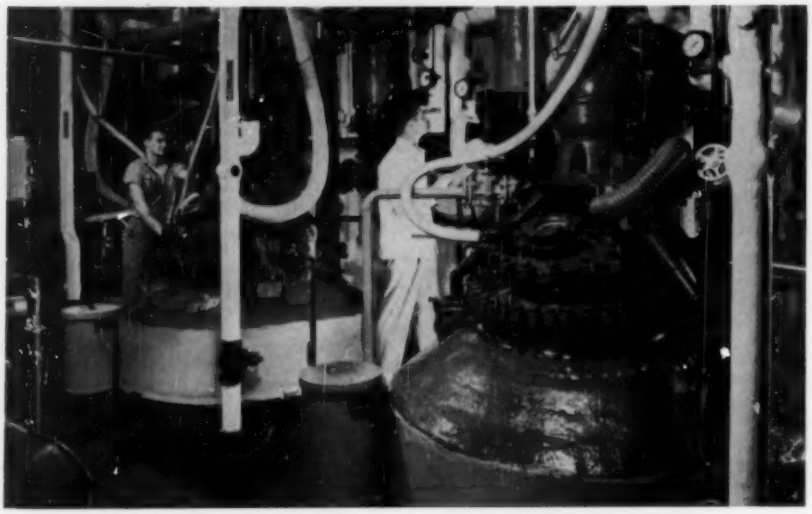
The hurried, harried, chemical engineer reads a review of a book not in his field of specialization to get the answer to at least one important question: Do I need to read this book? This reviewer answers by stating that this book by Bennett and Franklin is an excellent one for the engineer who realizes or is willing to believe that something major is happening in the

(*Continued on page 26*)

Corrosioneering News

Quick facts about the services and equipment Pfaudler offers to help you reduce corrosion and processing cost.

Published by The Pfaudler Co., Rochester, N.Y.



How DPi, Leading Vitamin E Producer Maintains Absolute Product Purity

Concentrating and purifying Vitamin E from natural vegetable oils is a delicate job. It's the "house specialty" of Distillation Products Industries, a division of Eastman Kodak Company.

By molecular distillation, DPi produces tocopherols in a number of forms. In every phase of their process –particularly the final step–extreme care must be taken to protect these products from contamination.

Critical Stage

The final stage in DPi's preparation of Vitamin E requires the protection of Pfaudler glassed steel reaction kettles. Fortified with an acid-alkali resistant inner surface, these reactors resist all forms of chemical attack, protecting the product from contamination.

Use of Pfaudler glassed steel equipment typifies the care that has made DPi a leader in the research and production of Vitamin E, as well as Vitamin A and distilled monoglycerides.

You too can profit by using Pfaudler glassed steel reactors. They are available in a complete range of capacities, from laboratory to full-scale production. When you make use of the custom features Pfaudler has incorporated in their standard design, you are able to get delivery on these reactors within two weeks.

How to Cool Off a Heat Exchanger Problem

With new processes on the horizon every day, Pfaudler engineers are receiving more and more requests for special features on heat exchangers.

To save you money on these designs, they have found that Pfaudler "flexible standard" stainless steel heat exchangers can be used as the base unit in a high percentage of cases.

For example, nozzles of any size – either flanged or threaded – can be installed in any position. And new production line methods make possible rapid deliveries – as few as 7 days!

To solve your problem, Pfaudler sales engineers can select from a complete line of heat exchangers – fixed tube sheet, single or multipass, tube and/or shell side stainless steel units. Shell diameters range from 4" to 24" in four basic types of construction: fixed tube sheet . . . outside packed floating head design . . . internal floating head . . . U-tube bundle. Most have removable tube bundles.

To take the heat off that heat transfer problem, discuss it with your Pfaudler representative. He has plenty of equipment to choose from.

Tall Story Lies Behind This Canadian Column

Two-thirds of this giant column was fabricated from stainless steel. The rest is carbon steel.

Seventy-seven feet high, the column projects into the sky above Canadian Chemical Company's plant at Edmonton, Alberta. It is a good example of the type of design and fabricating attention your problem will get when you turn it over to Pfaudler engineers.

In this case, a column was needed for a big, and very specific type of job. Seventy-seven feet high by 54 inches in diameter, it required custom fabrication.

Giant column has 40 sieve trays, is made of two types of steel.

Ordinarily, Pfaudler engineers are able to use economical standard units to solve problems of distillation, fractionation, stripping, bleaching and absorption. This saves you money, gives you the advantage of interchangeable components and uniformity of equipment designs.

To give you long-life equipment, Pfaudler offers a complete range of corrosion-resistant materials. This includes stainless steel, Hastelloy, monel, nickel, inconel, aluminum, glassed steel, and others.

Cut your equipment costs, and get the advantages of unbiased selection of construction materials, with Pfaudler glassed steel and alloy columns.

MARGINAL NOTES

(*Continued from page 22*)

general theory and practice of data collecting, especially in unprecedented or complex situations, and who wants to find out how to use modern statistical tools.

The size of the book is an indication of the gap in formal education that is to be filled. The engineer who is not ready to invest a hundred hours of study will not get to the parts of this book that really pay off, namely chapters 7 and 8. He will, however, soon recognize that the cost of the book is an almost irrelevant detail.

This book has been called a reference work or a handbook of applied statistics. Actually, it is a first-rate introductory and intermediate text. Well adapted for individual study, "Statistical Analysis . . ." requires only the usual mathematical background of chemical engineers.

Statistical methods are being developed so rapidly that several advances directly usable by chemical engineers have been published since this book was set in type. It is only in this sense that some may feel that the book is already a little outdated.

Results of Selected Laboratory Tests of an Ionics Demineralizer, by Ionics, Inc. Research and Development Report No. 1, Saline Water Conversion Program, U. S. Dept. of Interior (April, 1954).

Reviewed by Thomas K. Sherwood, Massachusetts Institute of Technology, Cambridge, Mass.

There has been much interest in ion-permeable membranes for industrial use, but little quantitative information has been published. The Saline Water Conversion Program is to be complimented for its preparation of a report summarizing the experimental demineralization studies carried out by Ionics, Inc., under government contract. Data are reported on a pilot-plant unit of two stages, each having 25 cell pairs of 1.3 sq.ft. cross section. The effects of the principal operating variables are shown graphically for the production of irrigation-quality water from several natural brackish waters, and from diluted sea water. Cost estimates for a large plant (75,000,000 gal./day) indicate that the process may be economical for the brackish waters, though doubtful for sea water.

what's in this issue...

HIGHLIGHTS of the technical articles—

Minerals Processing - p. 3-J; Ralston, Bureau of Mines takes a look back, and predicts a strong future for chemical engineering in helping to bring about a revolution in the minerals field. It seems that many techniques common to the process industries are making possible economic recovery of iron, copper and a number of hitherto "rare" metals from ores and tailings-dumps previously considered unworkable.

Filtration - p. 6-J; Blasewitz & Judson of the Hanford Atomic Works reveal that the best means for removing hideously dangerous radioactive particles from contaminated air uses a mat of glass fibers. Until recently, Hanford used sand beds, but has converted. The information assembled by these investigators may very well be of help to those with more ordinary trace-particle collection problems.

Economics of Ammonia Mfr. - p. 12-J; Duff of Fluor Corp. compares the various routes for making NH_3 starting with hydrogen from (1) natural gas, (2) residual oils, (3) coal, (4) coke-oven gas, and (5) from refinery catalytic reformer off-gas. Typical capital investments plus costs of materials, utilities and other expenses are used to obtain NH_3 manufacturing costs in plants of 100 & 200 tons/day capacity.

Liquid-Liquid Extraction (p. 17-J) has in a relatively short time skyrocketed into importance because of developments only recently announced which contributed materially to our ability to make pure enough uranium to explode in bombs and fuel our power-producing reactors. Now, Major & Hertzog come along with an extraction column design method backed with experimental data, which considerably simplifies the work of the chemical engineer.

Quality Control - p. 22-J; How Dow Chemical has managed to improve the quality control over their processing and products at their great Freeport, Texas works, is described by author Rio. The method is based on statistics, which are employed to realistically appraise a series of processing steps, to warn when significant process changes take place. Sometimes this technique is called "operations research."

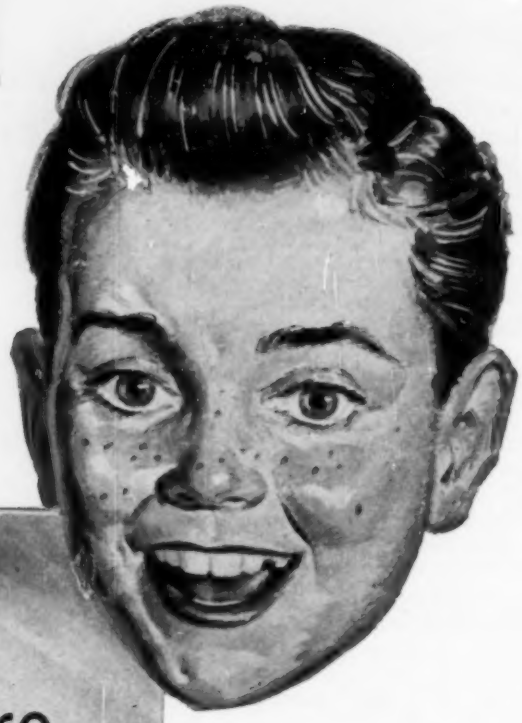
Mixing - p. 26-J; The mixing of finely divided solids has long been based on practical experience. Now we are fortunate in being able to present an article by Weidenbaum & Bonilla which has been termed by a reviewer "something finally being done in an important field of great general interest." Another calls it a major step in the transition from "qualitative to quantitative evaluation, which means sampling with statistical evaluation of results."

Process Control (p. 36-J) will be aided as chemical engineers become more aware of what can be accomplished with strain gauges - tiny webs of hair-fine wire that shrink and grow in cross-section as the surface to which they are cemented distorts. These changes affect their electrical resistance, which makes them useful signalling devices. The article by Jones (Ruge-deForest) provides "how-to-use" information.

C.E.P.'s Annual Directory of Theses begins on page 39-J. This is an up-to-date listing of doctorial theses in chemical engineering, similar to that which has proved so popular in past years. Who uses it? We are told it has a high appeal to industrial people, who are glad to know exactly where to go to lay their hands on information developed in the great academic institutions. Special Feature: An introduction by Ray Ewell of National Science Foundation, who discusses Trends.

Construction Costs - p. 44-J; When you're considering a new process plant, or even designing one, how much will you have to spend for the so-called "utilities" and "service facilities"? Long a moot question often entailing a number of bids from specialized contractors, Bauman of Chemical Construction Corp. (N. Y.) reveals a good bit about Chemico's experience with these items. No need to comment on this coming right out of the "horse's mouth"!

J.B.M.



stainless steel, too, means more than a shining face

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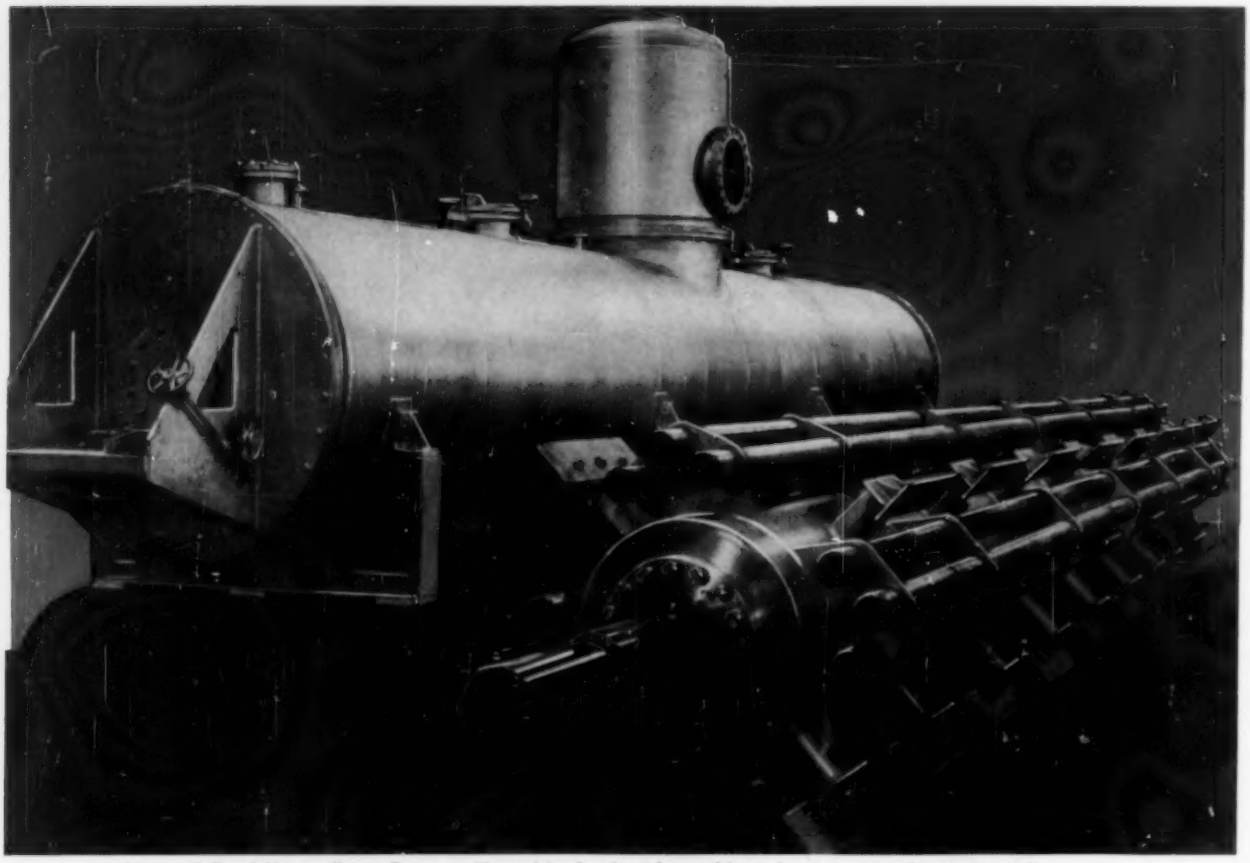

Buflovak Vacuum Rotary Dryer—with revolving heating tubes and heated agitator arms shown separately

Buflovak Vacuum Rotary Dryers provide low temperature drying with agitation . . . and recovery of solvents

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If your needs require special equipment, our engineers have the practical experience and technical know-how to design and build dryers for any special application. One example is special agitators for breaking up materials that form lumps, thereby reducing them to a uniform powder during drying operation.

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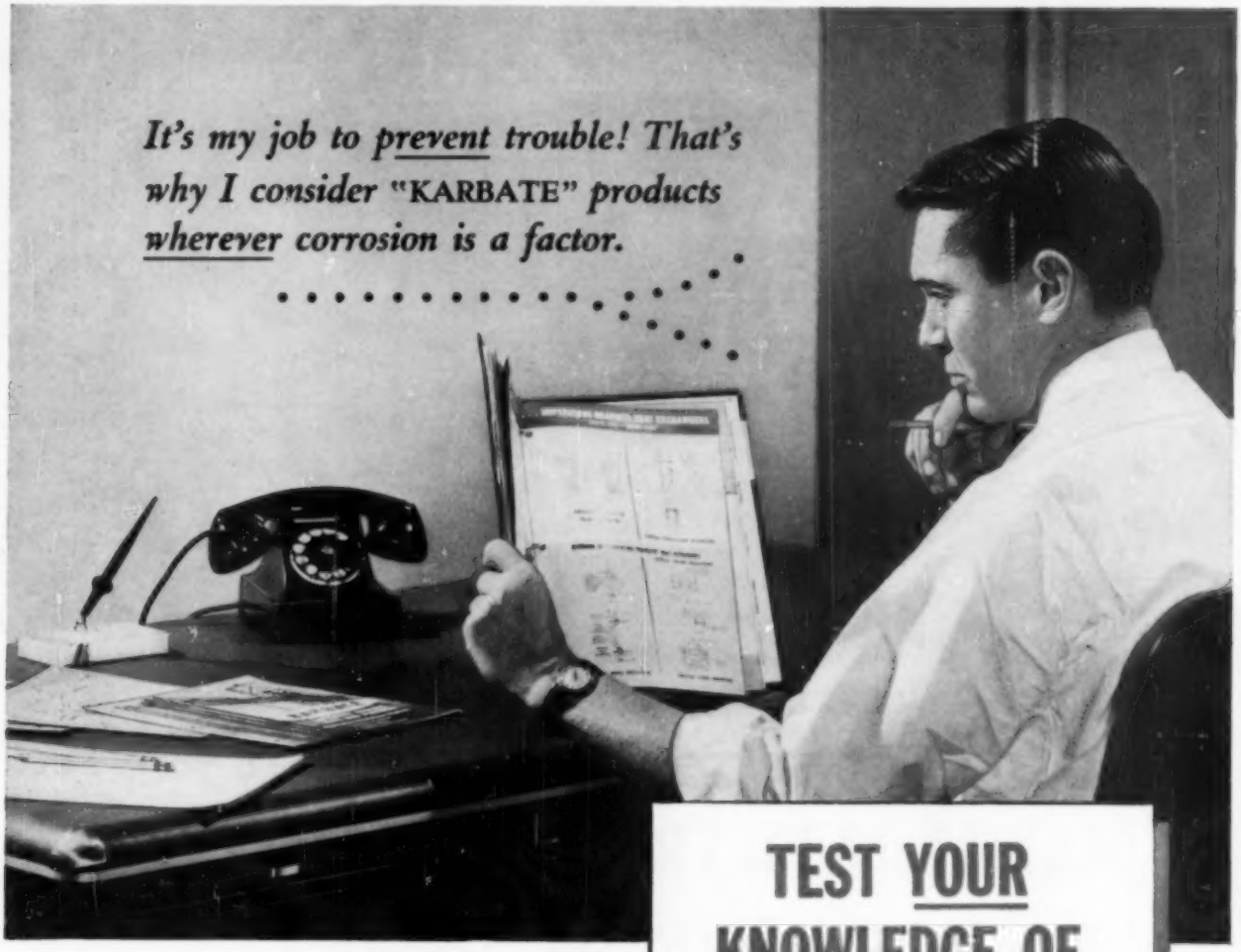

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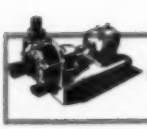
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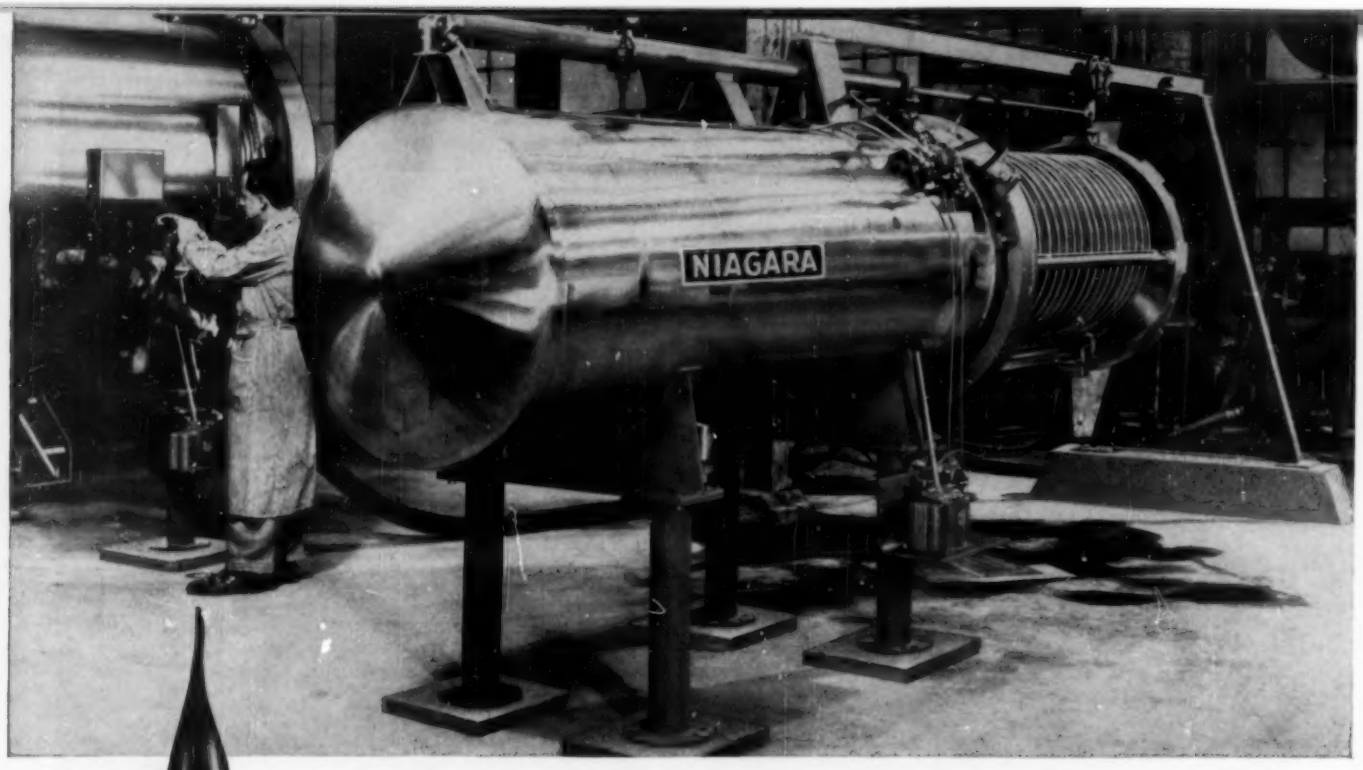

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opinion and comment

Looking Ahead

As your new president, I am using this opportunity to discuss with you some of the more important matters which are likely to engage our attention during the coming year.

To my mind one of the most important of our tasks is to help the young men who are coming up in the profession to gain a true professional spirit. The essence of this is rendering service to others, trying to do the very best job that one can under the given set of circumstances, continually striving to improve one's skill and competence in specific areas. It means that one does not put monetary reward first and that he does not confine all activities in relation to the job within a prescribed and limited number of hours per week. Let me emphasize that I do not minimize monetary compensation. The pay the engineer receives should be in proportion to his worth. My point is that he should put his sight on increasing the worth and not the pay envelope. The latter will take care of itself if the former is emphasized. Furthermore, there is no greater reward than the satisfaction that comes from work well done and from gaining the respect of one's fellow workers.

What can the Institute do to help inculcate the true ideals of professional conduct in the young engineers? This is a difficult question and I do not see any simple answer. It is partly the responsibility of the older members of the society who are in a position to influence the younger men. These older members can help by using every appropriate occasion to assert and reemphasize some of the simple and elementary truths that form the basis for the true professional attitude. This is also the direct responsibility of all those who have management responsibilities in industry. If the engineer is to acquire the professional spirit he has the right to expect treatment as a professional man by his employer. He should be treated as one of the management team and not just a hired worker. Perhaps most important of all, management must see to it that he is given work of true professional grade.

Another subject I wish to discuss is that of the recognition and the prestige of the engineering profession. There are many ways of enhancing the prestige of the profession and I do not intend to enter upon any comprehensive discussion but confine myself to one single aspect. This is the idea of an Engineering Center which is now under very serious scrutiny by the five major engineering societies through the agency of EJC (Engineer's Joint Council). To me this is a very appealing idea and if carried to fruition it could make a very great contribution to this question.

For the benefit of those not familiar with the idea, I will sketch in the main outlines. It is proposed to construct an office building which will house the headquarter's offices of the five major engineering societies—by this I mean Chemical, Civil, Electrical, Mechanical, and Mining and Metallurgical—and perhaps others who may wish to become associated later. By bringing all segments of the profession under one roof there will, I hope, develop a greater solidarity, a greater tendency to work together on problems common to all branches of the profession. There are many such problems and it seems to me that all engineers have enough in common so that all stand to gain by united action.

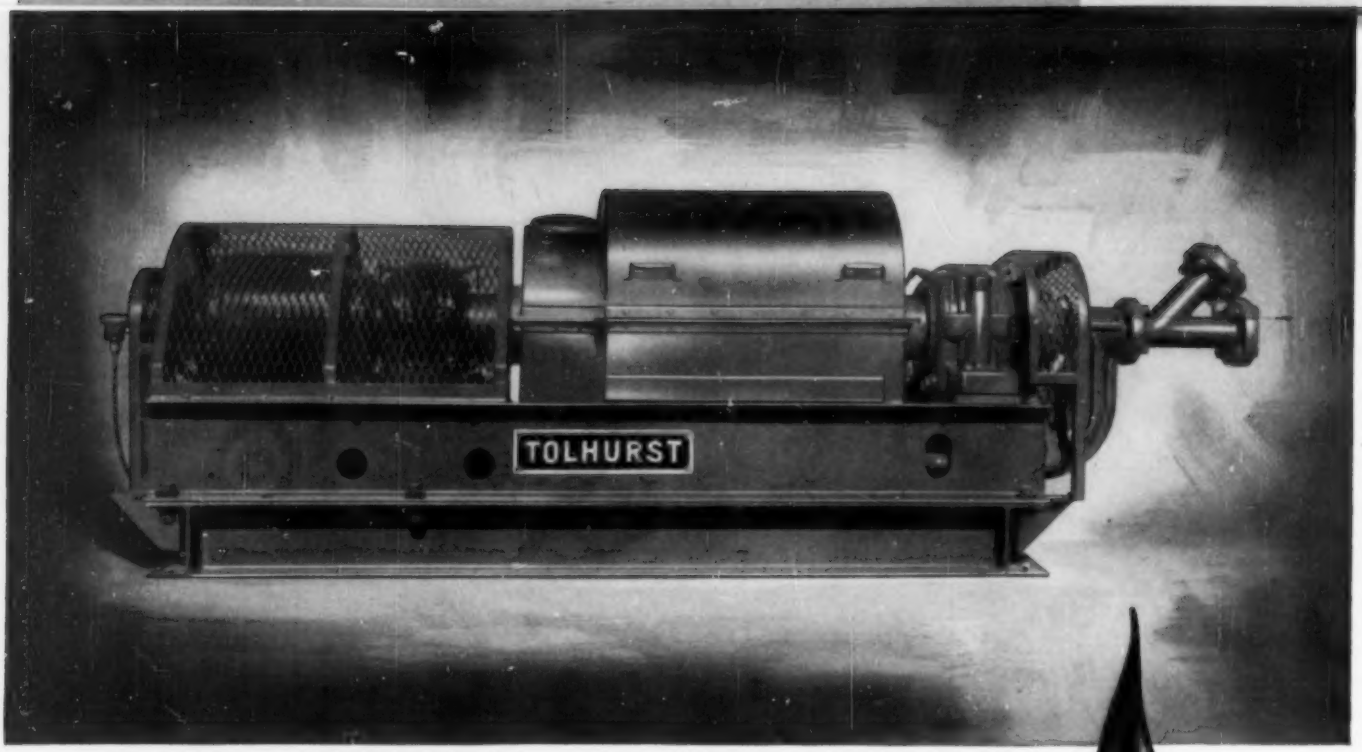
An Engineering Center would be a kind of monument or symbol which would tend to increase the solidarity of the profession and help to focus attention on the importance of engineering to the life of this nation.

Let me close with one more thought that comes close to home. It is common for the members of a society such as ours to ask, "What is the Institute doing to help me?" I would just like to throw the gears into reverse for a moment and ask each of you to ask himself—what can I do for the Institute? I happen to have the old-fashioned idea that you get about as much out of anything as you put into it, no more, no less (come to think of it I guess this is really nothing but the First Law of thermodynamics, but applied to human affairs). In other words let me urge all members and more especially the younger ones to see if there isn't some way in which they can serve the Institute—perhaps not always in very direct ways such as serving on Committees but in many indirect ways.

Enough of sermonizing by your new president. Let's all work together during the coming year and let each one of us dedicate just a little of his time to the Institute and to the Profession.

Barnett F. Dodge
President,
American Institute of Chemical Engineers

Specialists in Liquid-Solids Separation



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The new Tolhurst "Maxi-Flex" Continuous Centrifugal has been under field and laboratory tests for more than three years. It has fully proved its ability to handle a wide variety of materials with amazing speed, efficiency and economy. Perhaps this is the equipment you need to improve your operation. May we tell you about it?

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In this paper author Ralston explains the historic and technologic background for the trend towards adoption of modern chemical engineering techniques on the part of minerals processors. The paper was presented at R. H. Ewell's symposium on Role of Chemical Technology in Resources for the Future, at the Glenwood Springs, Colo., A.I.Ch.E. meeting.

extractive metallurgy increases mineral reserves

Oliver C. Ralston

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The title of this paper can be amplified into an axiom: Improved extractive metallurgy will increase usable reserves of minerals. It is therefore my task to point out just how this is likely to happen during the time between now and 1975 in view of trends observed during my active career and the history of the previous years. What is past is prologue, and a prologue gives us hints of what is coming.

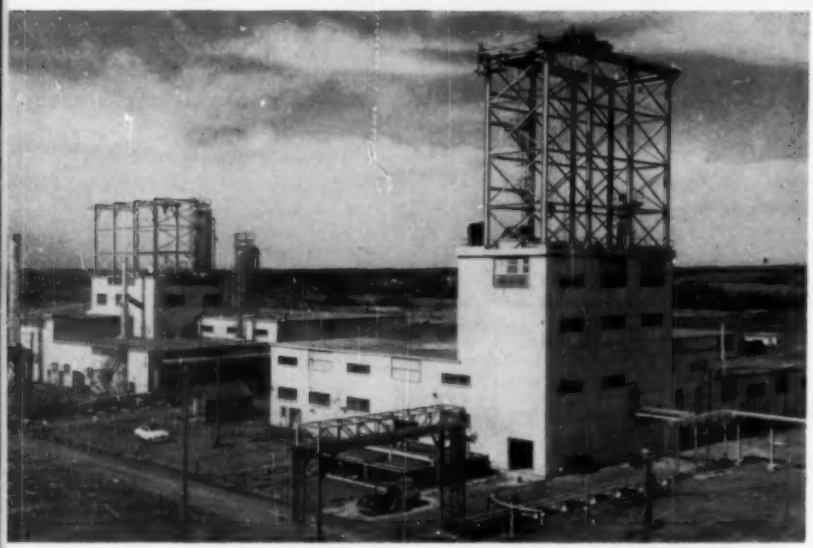
I shall take the liberty of including mechanical concentration of ores and minerals as the first step in extractive metallurgy, even though it is not a chemical process. Extractive metallurgy consists largely of chemical processes, hydrometallurgical, pyrometallurgical, and electrometallurgical, and is therefore a branch of the broader subject chemical engineering. The raw materials for all inorganic chemical processing are won from mineral deposits, brines, oils or gases taken from the earth.

History

Looking back over the years since the California gold rush we see that the first gold came from the gravels of placer deposits and was won by mechanical processes: pans, rockers, riffles, blankets, concentrating tables, and jigs, successively. As we became more sophisticated we invented and used more complex machinery. When the original lodes carrying gold were discovered and mined, the methods were further improved, and chemical processes entered the picture—

first amalgamating with mercury, then chlorinating the gold to get it into solution, and finally, about the turn of the century, using solutions of cyanides. Early in the extraction of lead or copper from ores it was noted that the lead and copper when smelted were accompanied by gold and silver, and now most of the precious-metal production in the United States is recovered pyrometallurgically as a coproduct with copper or lead. Fundamentally the extractive metallurgy of gold and silver has remained static since 1910, but engineering improvements in the fundamental processes have continued, and with each improvement the grade of material that can be treated economically has been lowered. Placers and concentrating mill tailings are reworked and old smelter dumps retreated, and so the process of technologic advancement goes on. Most recently the cyanide tailings of the gold mines on the Rand in South Africa are being taken up to recover a little more gold but particularly to win the uranium that was little known and unmarketable in the earlier days. In the same way other old gold and silver dumps have been re-treated to capture tungsten and similar minerals. Dumps of the present generation become precious resources in future generations.

What has just been said about gold is repeated in many other commodities. Bauxites have been mined mainly for their alumina content but have always carried minor amounts of iron oxide and titania minerals, and the sodium aluminate solutions circulating in the alumina plants have had to be purged periodically of gallium, still largely unsalable. More recently the Arkansas bauxites proved to carry columbium associated with the iron-titanium minerals. The old adage holds true implacably—impound your tailings for reuse, and keep up the search for new deposits.



Courtesy—Sherritt Gordon Mines

One of the most modern chemical metallurgical plants in existence for recovery of nickel metal from nickel copper sulfide concentrate produced by Sherritt Gordon Mines at Lynn Lake, Manitoba. The concentrate is shipped to the plant at Fort Saskatchewan, Alberta, where nickel, copper, and sulfur are extracted using ammonia as a leach. It was designed and constructed by Chemical Construction [Inter-American] Ltd., and based on processes developed in a complete pilot plant operated by Sherritt Gordon Mines at Ottawa, Canada.

Sources

This last statement brings up the point that the metallurgist must be supplied with something containing the desired mineral products; whereas he can rework old tailings or slags he must also be supplied with primary ores. Exploration has become a highly developed art and costs less every year. Outcrops that in older days were investigated by pick and shovel are now frequently opened up with a bulldozer, which can make a tremendous cut in a few hours in comparison with the man-hours that once were required. Geophysical exploration often indicates deposits that do not even show at the surface. It must be followed by drilling to supplement the indications of the geophysical instruments. The metallurgist must be given part of the samples to determine workability and practicability of recovery of the mineral matter disclosed. He has a function even in the exploration phase. The mining engineer needs to know what can be done metallurgically before he devises plans for mining. The criteria of today will be antiquated in 1975. Technologic improvements will go on in all phases of the industry if enlightened management is to convert mineral deposits into wealth. Unworkable deposits of today may be abandoned and even covered up but must not be forgotten. They will be the nation's bread and butter tomorrow. They may now be classified as economically marginal or even submarginal, but some day they will be usable.

This continuous flux in workability usually entails the treatment first of high-grade materials and then lower and lower grade materials. Sometimes it advances from unworkable complex mixtures to processes recovering many products jointly in order to pay the expense. During my own lifetime I have seen economic copper ore advance through each decade from ores containing 10% or more copper to ores lower and lower in grade until now many deposits with only 1% copper are often workable, particularly if they are large. This trend usually results because the volume of low-grade ore as a rule is much larger than that of high-grade ores. The manganese deposits of this country have been gouged by mining only for high grade, but the tonnage of lower grade material is sometimes astronomic in comparison. This applies particularly to iron ores of the Minnesota and Michigan ranges. The present entry into taconite mining is made possible through the advancements made by both mining and metallurgical engineers, including the "millmen" who concentrate the taconites.

Hydrometallurgy

Hydrometallurgy is one branch of the subject that appears to have a greater future than was appreciated only 15 years ago. Gold ores came to new life when cyaniding was adopted 50 years ago. Some copper deposits were highly oxidized near the surface, and hydrometallurgy appeared to be the only solution; so we have had copper leaching for over 40 years. In addition to treating primary ore, water has been sprayed on the low-grade stope filling of earlier mining operations, and copper-iron sulfate solutions have come out at the lowest level of the mines. Mine dumps of broken submarginal ore have likewise been subjected to trickle leaching by water or dilute acid solutions. Underground leaching is frequently mentioned as a method of the future. This, how-

ever, I regard as whistling in the dark if the deposit is not at least primarily shattered by blasting methods to permit access of trickling solutions.

The newer hydrometallurgies being developed at present are designed for treating finely divided concentrates made by flotation from low-grade ores. An advantage of hydrometallurgy is that many elements can be taken into solution simultaneously and individually precipitated, to get single products or groups of products that can be handled by existing metallurgical extractive methods. Witness the present series of processes for treating mixed low-grade ores of nickel, cobalt, copper, etc., which are under very active development. Many of these new processes involve the use of pressure vessels in both dissolving and precipitation, a practice that was anathema only a few years ago. However, pressure vessels are in use in industries whose products are worth much less per pound than are metals, and the time has come when metallurgists should drop their fear of pressure reactions. In the hydrometallurgy of zinc, a host of by-products has been made commercially possible: cadmium, lead, copper, silver, gold, thallium, cobalt, germanium. Mixed ores and scrap metals, if subjected to suitable hydrometallurgies, can capitalize on losses now tolerated, whether or not pressure vessels are used at any stage of the process.

Electrometallurgy

Electric furnaces with their fine controls are coming to be used more for both ferrous and nonferrous metals. Large amounts of the finer steels are now electrically melted and refined. Copper ores are being smelted, and in Sweden even lead ores are smelted electrically. Vaporized products can be more easily gathered and reliance placed on their being recovered if they enter the furnaces. Electric smelting of zinc has been with us for some years and is an example of the use of vaporization in large smelting units instead of the old hand-fed horizontal retorts, which formerly lost vaporized by-products, like cadmium.

Miscellaneous Refining Processes

Filtering of liquid metals has been perfected only for the low-melting metals: lead, tin, and aluminum. Just above the freezing point of the main low-melting metal, associated impurities often crystallize out and can be filtered through a sand bed. The tin-iron alloy known as the bane of the tin smelter can be filtered out, roasted, and returned to the smelting furnace, and the filtered tin is of a higher grade. Centrifuges can be used for some of the jobs now being done by filters. Scraps of a variety of metals can thus be fractionated and a higher recovery made of useful products. These methods of refining will grow.

Superrefining of some otherwise pure metals has grown since Bell Telephone Laboratories first refined germanium by *zone melting* to a product in which impurities were present only in parts per billion. A long trough filled with germanium is heated by a narrow induction coil, which melts only the metal within it. If the coil slowly advances from one end to the other, the metal melts, the pure metal freezes out behind, and the impure liquid metal advances with the melting coil. Several passes will concentrate all impurities in one end. The method has also been applied to aluminum of 99.9% purity to convert it to metal of such ultrahigh purity that it can be cold-worked without work-hardening and has a degree of ductility never heard of, as well as greatly increased conductance.

Another low-grade aluminum refining process applicable to scrap is the subhalide process of refining. Aluminum chloride is highly volatile and will react with metallic aluminum to form the monochloride AlCl, which is also volatile but which on cooling disproportionates into aluminum metal and aluminum trichloride vapor, $AlCl_3$, which can be reheated and recirculated over the mass of impure aluminum being refined. This is another process in only its very early stages of development, which likewise requires proper engineering attention to make it commercially useful.

Pure Metals

The pure metals often have quite different properties from the commercially pure grades. This has been noted with electrolytic manganese and electrolytic chromium, both of which are now in a stage of more rapid development. No one knows what to do with pure vanadium in large amounts, but the means of making it are now developed, and the market will grow, just as surely as electrolytic manganese grew, although it took over 10 years for it to gain acceptance.

High-purity metals that have already captured the imagination of the armed forces are titanium, zirconium, and their triplet, hafnium, only beginning to attract attention. In 1940 it was hard to sell more than a few hundred pounds of pure metal in a year. This is still true of pure columbium, whose alloys have become so popular that everybody hopes no new uses or products will be invented. The same was true of beryllium. We have large domestic supplies of titanium and zirconium, and I venture to predict that hafnium will become so popular that we shall be embarrassed that there is so little of it in the zircon ores. However, just as uranium was once a drug on the market and thought to be quite rare, we may expect adequate supplies to be found when the financial reward is great enough. Let progress take its course, and adequate supplies of columbium, cobalt, selenium, germanium, beryllium and the others will be found through exploration.

Chemical Processes

The hydrometallurgist is already beginning to use ion exchange, liquid-liquid extraction, and chromatographic separations to prepare desired metals. This applies particularly to the rare earths, both of the lanthanide and actinide groups, formerly regarded as almost hopeless mixtures. The necessity of separating these mixtures in permanent or radioactive isotopes has spurred the Atomic Energy Commission to pioneer in many of these new separative processes. These two types of processes use fractional differences in solubility or adsorption respectively, and often the differences are not sufficient if the ordinary simple ions in solution are handled. Complexing of the soluble compounds has often created greater differences that sharpen a separation. The researchers are now combing the old literature on the complexes of the various cations or anions, once of purely academic interest, but now a mine of useful information. Pure science of today becomes applied science of tomorrow. In ion exchange alone rapid improvements in exchangers, tailormade for each job, are taking place. Whereas only solid exchangers were originally used, liquid exchangers can also be used and plastic diaphragms made of ion exchangers. Opportunities to obtain countercurrent flow in ion exchange columns and chromatographic columns and thus to create continuous processes have resulted. I see in these new processes a tremendous field for development in metallurgical and chemical engineering. Much of it will occur in the next 25 years.

Presented at A.I.Ch.E. Glenwood Springs meeting, September 12-16, 1954.

Illustrations on page 3-J supplied by the Dorr Company.

filtration of radioactive aerosols by glass fibers

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The disposal of radioactive waste gases from the plant-scale processes at the Hanford Atomic Products Operation presents a problem that is of considerable importance in the plant operation. This paper is concerned with the efficient removal of the particulate matter suspended in the contaminated gas streams and represents the final report of an extensive investigation of the filtration properties of glass fibers undertaken to develop a filter unit having better performance characteristics than those of the initially installed sand filters. The program was divided into three primary studies consisting of: (1) the correlation of collection efficiency under start-up conditions with the superficial velocity of the gas stream and the bed depth and packing density of the various types of glass fibers, (2) the correlation of flow resistance under start-up conditions with the same variables, and (3) a study of the expected service life of glass fiber filters. The results of the development program led to the design of glass fiber filters capable of operating at a higher superficial air velocity than the plant sand filters and with a greater efficiency, a lower flow resistance, and a greater life expectancy. Such filters have been constructed and are presently employed at the Hanford Atomic Products Operation. The measured efficiency and flow resistance of the large-scale filters are in excellent agreement with the design data. The operating performance of the fixed-bed filters at this plant has been highly satisfactory.

The waste gases emitted from production and laboratory processes in the Hanford plants operated by the General Electric Company for the Atomic Energy Commission contain radioactive fission products which could result in the potentially hazardous contamination of the areas surrounding the plants if they were discharged directly to the atmosphere, (*1, 2, 3*). In accordance with the strict safety and health physics policies existing at the various AEC sites, considerable efforts have been expended to prevent any widespread contamination by either radioactive gases, such as I^{131}, or by radioactive particulate matter suspended in the stack gases, (*4, 5*). This paper represents the final report of an extensive program undertaken at the Hanford Atomic Products Operation to develop a means for the efficient removal of submicron particles from the contaminated gas streams (*6*).

The design specifications to be met in the filtration of radioactive aerosols are more rigorous than those of the ordinary commercial collector. Furthermore, since the collection of large amounts of contaminated material in one place is inherently dangerous, the stringent requirements of AEC safety policies restrict considerably the possible methods by which the air pollution problem may be solved. A brief summary of the specifications which were established as the development and design goals for the Hanford process air filters is presented in Table 1. It is evident that the more common types of commercially available dust collectors, such as cyclones and scrubbers, fail to meet one or more of these specifications.

An expedient solution to the problem of removing radioactive aerosols from the Hanford waste gases was a fixed-

Table 1.—Air Filter Specifications

1. A collection efficiency of 99.99% for submicron particles present in low concentrations.
2. A minimum initial flow resistance commensurate with the desired collection efficiency.
3. A minimum of maintenance in the continuous operation of the unit.
4. A life expectancy in terms of years.
5. Containment of the collected radioactive materials in a manner that will not cause a subsequent disposal problem.

bed filter consisting of successively finer gradations of sand placed in a large underground container and suitably equipped with air distributors, plenum chambers, and duct work (*7, 8, 9*). The first fixed-bed filters of this type were installed in the fall of 1948. The characteristics of the units agree well with the specifications in Table 1 and the filters have performed in a highly satisfactory manner to the present time. The sand filters, however, are bulky and expensive, and their measured efficiency (in the order of 99.7%) is not adequate for the more highly contaminated gas streams.

It was suggested by Lapple that the substitution of glass fibers for sand might lead to some improvements in filter design and operation (*10*). Since the results of preliminary tests were favorable, an extensive investigation of the filtration characteristics of glass fibers was initiated. The program was divided into three primary studies consisting of: (1) the correlation of collection efficiency under start-up conditions with the superficial velocity of the gas stream and the bed depth and packing density of various types of glass fibers, (*2*) the correlation of flow resistance under start-up conditions with the same variables, and (3) a study of the expected service life of the glass fiber filters. Complete details of the experimental procedures and graphs of all the data obtained on the various types of glass fibers are available (*6*).

The Collection Efficiency of Glass Fiber Filters

The efficiencies with which glass fiber beds remove suspended particulate matter were measured under field conditions by employing as a testing medium the radioactive aerosol discharged from one of the plants' process-cell ventilation systems. Particle size determinations made with a Modified Cascade Impactor indicated that the radioactive particulate matter in the process-cell air was predominantly in the submicron range. (Experimental values of the geometric mean particle diameter varied from 0.2 to 0.7 μ.) No attempt was made to determine the size distribution of the uncontaminated particles since the efficiency tests were to be based upon radioactivity measurements. Other studies revealed that the dust loading of the air entering the process cells was 0.01 to 0.02 gr./1,000 cu.ft. and that the particle concentration of the effluent air was in the order of 0.2 to 0.4 gr./1,000 cu. ft. The figures indicated that the preponderance of both the contaminated and the uncontaminated particles of the gas stream originated in the process cell area. Particle concentrations of this magnitude are sufficiently low to make filtration by a fixed bed highly attractive in terms of expected filter life.

It should be noted that the experimental results presented in this paper are directly applicable only to systems wherein the size distribution and concentrations of the suspended particulate matter are comparable to those of the testing media. In cases where a significant difference in particle size distribution exists, for example, the collection efficiency of a given fibrous material may be appreciably different.

EXPERIMENTAL EQUIPMENT

The supply of process-cell air employed in testing the glass fiber units was withdrawn from a sample port located in the main duct system connecting the process cells and the plant sand filter. The air stream was drawn through the experimental glass fiber bed, metered in an orifice section, decontaminated in a Standard Chemical Warfare Service box-type filter (rated efficiency of 99.9%), and exhausted to the atmosphere through a steam-operated evacuator. A typical unit in which the fiber glass was tested consisted of a piece of large diameter (between 4 and 10 in.) pipe flanged at both ends and provided with pressure taps near the top and bottom for flow resistance measurements. Above the bottom pressure tap a screen was welded inside the main body to serve as a support for the filter bed. The fibrous glass was then packed to the desired density and depth.

During the course of an efficiency determination, continuous samples of the gases upstream of and downstream from the filter unit were withdrawn from the test stream. The sample aliquots were passed through suitable orifice sections and monitoring stations wherein the particulate matter in the samples were removed by passage through CWS Type 6 filter papers. The collection efficiency of each experimental fiber bed was determined by measuring the amount of radioactivity collected on the upstream and downstream monitor filters. Two means of obtaining these values were available, a radiation survey meter and actual laboratory analysis of the radioactivity on the monitors. The precision of each of the two methods was determined by statistical analysis to be $\pm 0.3\%$.

FILTER FORMULA

The measured collection efficiencies for the various types of glass fiber beds were correlated with the controlled variables of superficial air velocity, bed depth, and fiber packing density by a mathematical expression very similar to the general equation which may be derived for the initial filtration characteristics of a laminar-type filter operating at only its rated superficial velocity. If it is assumed that the aerosol is homogeneous and that each filter layer removes the same average fraction of particles, the rate of deposition is

$$-\frac{dW}{dN} = MW \qquad (1)$$

Rearranging and then integrating the relation over the total filter results in

$$\int_{W_i}^{W_o} \frac{dW}{W} = -M \int_0^{N_o} dN \qquad (2)$$

$$\ln \frac{W_o}{W_i} = -MN_o \qquad (3)$$

$$\frac{W_o}{W_i} = e^{-MN_o} \qquad (4)$$

Since, by definition

$$a = \frac{W_i - W_o}{W_i} = 1 - \frac{W_o}{W_i} \qquad (5)$$

$$a = 1 - e^{-MN} \qquad (6)$$

Such an expression applies only to laminar-type filters in which the physical characteristics of each layer are the same, for example, a unit comprised of a number of CWS filter papers. Glass fiber filters, however, involve other parameters, such as the bed depth and packing density.

dust collection

For purposes of convenience the collection efficiency was expressed in terms of a dimensionless decontamination factor involving common logarithms rather than natural logarithms. Thus

$$a = 1 - 10^{-DF} \qquad (7)$$

Introducing the decontamination factor into the exponential equation given above and including the parameters of superficial velocity, bed depth, and packing density give an expression suitable for the filtration of fibrous glass beds in the velocity range studied. In mathematical form

$$DF = -\log(1-a) = CL^{a}\rho_p{}^{b}V^{e} \qquad (8)$$

To determine the exponents for each type of glass fiber, the variance in the collection efficiency was measured in a series of test runs in which only one parameter was varied at a time. Thus, to obtain the velocity exponent, the same bed depth and packing density of a test unit were retained throughout a number of runs so that the following correlation of efficiency and superficial velocity was in effect:

$$DF = -\log(1-a) = C'V^{e} \qquad (9)$$

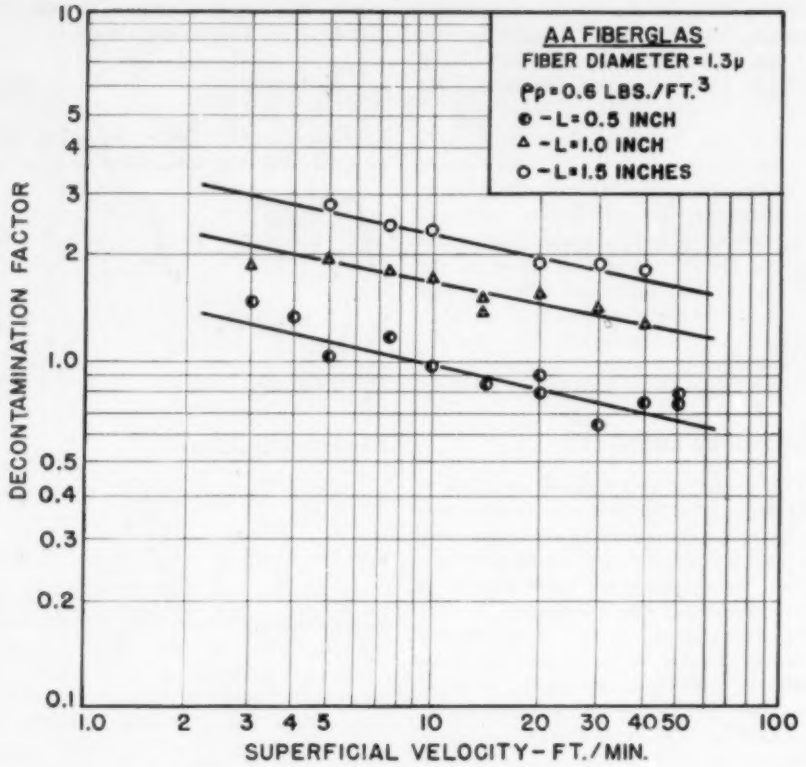

Fig. 1. Graph of decontamination factor vs. superficial velocity.

and

$$\log DF = \log[-\log(1-\alpha)] = c \log V + \log C' \qquad (10)$$

The velocity exponent was obtained by plotting the data on a logarithmic graph of decontamination factor vs. velocity and measuring the slope of the line. This procedure is illustrated in Figure 1, where the velocity exponent of Owens Corning AA Fiberglas, a fiber having a mean diameter of 1.3 μ, was determined by employing test units with a packing density of 0.6 lb./cu.ft. and bed depths of 0.5, 1.0, 1.5 in. A similar procedure was employed to determine the exponents for the other parameters.

Table 2.—Efficiency Parameters for Glass Fibers

$$DF = CL^{a}\rho_{p}^{b}V^{c}$$

Fiber Number	Fiber Diameter μ	C	a	b	c
AA	1.3	4.6	0.8	1.0	−0.2
B	2.5	.....	...	...	−0.25
55	15	0.085	0.9	1.1	−0.4
115K	30	0.054	0.9	0.9	−0.4
450 115		.....	...	...	−0.5

DATA CORRELATION

A compilation of the collection efficiency data for the more promising glass fibers is presented in Table 2. For each type of glass fiber the value obtained for the bed depth exponent was less than one, which demonstrates the effect that particle size distribution has on collection efficiency. During the passage of a gas stream through a fibrous filter, the size distribution of the suspended particulate matter continually undergoes incremental changes brought about by particle deposition. Since the collection efficiency of an incremental layer of the filter is a function of the size of the particles passing through it, the median particle diameter continually shifts toward the particular size that most readily penetrates the filter. The net result is that the filter increment required to achieve a given collection efficiency increases in depth as the particle size distribution changes, or, in mathematical terms, the bed depth exponent for a given heterogeneous aerosol is less than one.

The value for the packing density exponent varied from 0.9 to 1.1. It is believed that the true value of this exponent is 1.0 and that the recorded variance was due to the experimental precision.

Throughout the velocity range of 0-75 ft./min., the collection efficiency of any one type of fiber decreased as the superficial velocity was increased, indicating that the predominant mechanisms of particle removal were flow-line interception and diffusion of the particles to the fibers with their subsequent adherence. A consistent lowering of the velocity exponent with decreasing fiber diameter was obtained. Since the mechanisms of particle diffusion and particle impingement are influenced in opposite directions by an increase in velocity (flow-line interception is independent of velocity), and since the effect of particle impingement is greater for smaller diameter fibers, the over-all effect should be a flattening of the low velocity portion of the decontamination factor versus velocity curves and a subsequent lowering of the velocity exponent.

Above a velocity of approximately 75 ft./min., however, the degree of particle removal gradually increased with increasing velocity. Because practical considerations, primarily those of flow resistance and filter life, restricted the application of deep-bed filters at the Hanford Atomic Products Operation to the velocity range of approximately 25 ft./min., this characteristic was not explored. It is believed that the reversal of the velocity exponent from a minus to a plus value was due to the transition from a diffusional process to particle impingement as the predominant, velocity-dependent, collection mechanism.

Although the data were not correlated on the basis of fiber diameter, it was observed that the efficiency was generally higher for the filter units having the smaller diameter fibers.

Flow Resistance of Glass Fiber Filters

The resistance offered by fibrous glass beds to the air streams passing through them was measured in a series of permeability tests in which atmospheric air was employed rather than the contaminated process-cell air. The pressure drop for each type of glass fiber was correlated with the operating variables.

The exponents, x, y, z, were determined in a series of pressure drop vs. velocity measurements which were made on a suitable number of filter beds, each of which had a different bed depth and packing density. Cross-plotting the data resulted in a general expression for the pressure drop of each type of glass fiber. The data for the fibers which were selected for detailed study are presented in Table 3.

The bed depth exponents, as would be anticipated, were one. The velocity exponents were each one, demonstrating that laminar flow exists throughout the flow range (5 to 100 ft./min.) which was studied. The value for the packing

Table 3.—Flow Resistance Parameters for Glass Fibers

$$\Delta\rho = KL^{x}\rho_{p}^{y}V^{z}$$

Fiber Number	Fiber Diameter μ	K	x	y	z
AA	1.3	0.082	1.0	1.5	1.0
B	2.5	.....	...	...	1.0
55	15	0.00043	1.0	1.6	1.0
115K	30	0.00020	1.0	1.5	1.0

density exponent was determined to be 1.5.

Comparative Life Expectancies of Glass Fiber Filters

The proper design of a highly efficient fibrous glass filter involves not only an adequate knowledge of the characteristics previously outlined but also sufficient information regarding the on-stream properties to insure a maximum life expectancy. When a particle is filtered from an airstream, it is assimilated within the bed and causes an incremental change in the operating characteristics of the filter by assisting in the removal of other particles and increasing the resistance to air flow. The low concentrations of radioactive and inactive particles in the process-cell air described above provided a convenient means of determining the filtration characteristics of fibrous beds under start-up conditions where filtration was due to the fibers alone and the effects of the filtered particles were immeasurably small. The use of the process-cell air to determine the comparative life expectancies of glass fiber units relative to the plant sand filter, however, would have been impractical. A methylene blue aerosol was therefore employed to provide a high dust loading and thus restrict the test period to a suitable time interval. It should be noted that, since the exact manner in which the assimilation of collected material continually changes the operating features of a filter is dependent upon the size distribution, concentration, and structure of the particles, the *quantitative* results of the methylene blue tests cannot be applied directly to field conditions involving particles of a different nature. The qualitative results, however, are extremely useful in the design of a filter having a maximum life expectancy.

EXPERIMENTAL EQUIPMENT

The methylene blue smoke that was employed as a test medium was generated by dispersing a dilute solution of the dye into the air and evaporating the resultant droplets. The formation of the liquid aerosol was accomplished by means of four aspirators, the design of which was originally proposed by Laskin and later modified by Enquist (*11*). The spray continuously formed by the aspirators was passed through a cyclone separator, where the larger droplets were removed. The mist-laden stream was then diluted with large volumes of clean air in a dilution chamber, which served to evaporate the water and stabilize the resultant smoke. The diameter of the solid particles so formed was a function of the dye concentration of the original solution. A 2% solution resulted in smoke particles having a measured mean diameter of 0.5 μ. The dust loading was 2 to 8 gr./1,000 cu. ft. of air.

Upon leaving the dilution chamber, the main stream was divided into eight parallel lines, each of which served a test unit. The parallel smoke streams passing through the fibrous glass units were individually metered in orifice sections, then collected into a header line containing a CWS box-type filter, and exhausted to the atmosphere. Pressure taps were incorporated at appropriate points in the filter units and the lead lines were brought to U-tube or inclined manometers. Sample ports were located directly downstream from the dilution chamber and at the extreme end of the header feeding the parallel units. These positions were operated continuously to verify the uniform dust loading of the gas entering the filter beds.

Calculation of the dust-loading of the smoke or the grains of dust entering a filter bed involved the measurement of the amount of dye collected on the monitor filters. The methylene blue was dissolved in ethyl alcohol, transferred to a known volume of water, and analyzed by a Beckman Spectrophotometer. The nominal precision of measurement was ±5%.

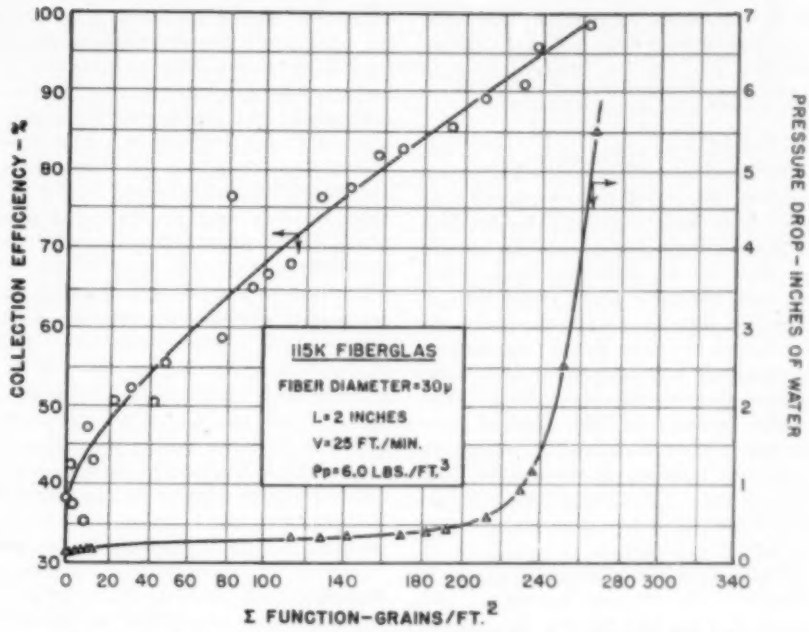

Fig. 2. Graphs of collection efficiency and flow resistance vs. cumulative grains of methylene blue passing to the filter per square foot of filter area.

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EFFICIENCY INCREASE STUDIES

The concept of mechanical filtration as a dynamic process which culminates in the "plugging" of the filter bed was demonstrated by measuring the average collection efficiency and flow resistance during the passage of an incremental amount of smoke to a test filter. The cumulative grains of dust passing to the unit per square foot of filter area plotted against efficiency and pressure drop values at a superficial velocity of 25 ft./min. for 2 in. of Owens Corning No. 115K Fiberglas packed at 6 lb./cu. ft. are presented in Figure 2. The early portion of the pressure-drop curve is relatively flat, whereas the corresponding efficiency values increase rapidly. As the slope of collection efficiency curve flattens, the pressure-drop curve becomes progressively steeper. Thus, the shapes of the two graphs can be interpreted in terms of each other. During the initial rapid rise of collection efficiency, the amount of material assimilated within the bed was not sufficient to bring about an immediate increase in flow resistance. Upon reaching high efficiency values, however, virtually all

of the material approaching the unit remained within the bed and, consequently, built up the pressure drop at a more rapid rate.

LIFE TEST DATA

To provide sufficient information regarding the on-stream properties of glass fiber beds to permit the development of a highly efficient filter capable of operating for a much longer period of time than the plant sand filter, a series of tests was performed wherein the useful filtration life of the various fibrous beds was determined as a function of the quantity of smoke particles passed to the unit. The basis of comparison chosen for the life expectancy tests was a model of one of the plant sand filters. The data which were obtained during one of the life tests are presented in Table 4.

Included in the table are the compositions of the various test layers, the depth of each test stratum, the velocity with which the unit was operated, the initial pressure drop of the bed components, the pressure drop increase to which the filter was carried, and the total quantity of aerosol which was passed to the unit during this time. In general the use of forefilters having a larger fiber diameter or a lower packing density increased the filter service life. The results show that the fibrous glass filter composed of AA Fiber at a density of 1.2 lb./cu.ft. and No. 55 Fiber at a density of 6 lb./cu.ft. would have a life approximately equal to that of a sand filter if the filtration areas were the same. If a protective layer of No. 55 Fiber at a density of 3 lb./cu.ft. is incorporated into the unit, the life of the filter will be approximately twice that of the sand filter. If a forefilter of No. 55 Fiber at a density of 1.5 lb./cu.ft. is incorporated, the life of the composite filter will be about twenty times that of a sand filter having an identical area. Since the glass fiber units are operated at approximately five times the linear velocity of a sand filter, the effective life extension is approximately four times that of a sand filter. If the assumption is made that this factor is applicable to the Hanford process-cell air conditions a glass fiber filter can readily be designed which will efficiently filter the process cell particulate matter for at least fifteen years without an excessive increase in pressure drop.

Table 4.—Life Test Results

Filter Media	Density (lb./cu.ft.)	Depth (in.)	Δp Increase (in. of water)	Cumulative loading (gr./sq.ft.)
Sand Filter		45	5.6	125
AA	1.2	0.25	0.1	
55	6.0	8	4.5	125
55	6.0	8	0.2	
55	3.0	5	4.5	300
55	3.0	5	0.1	
55	1.5	14	4.5	3,000

Notes:

(1) The superficial gas velocity was 5 ft. /min. through the sand filter and 25 ft./min. through the glass fiber filters.

(2) Cumulative loading refers to the cumulative grains of methylene blue passing to the filter per square foot of filter area.

The Design of Glass Fiber Filters

A convenient method of co-ordinating and summarizing the material presented in the previous sections is to give an illustrative example of a filter designed to remove suspended particulate matter in the submicron size range with an efficiency of 99.99% or greater. The filter formulation developed for the decontamination of the vent gases from one of the Hanford process vessels is presented in Table 5. The unit is 2.5 ft. by 5.5 ft. with an overall height of 4.3 ft. The cross-sectional area, 12 sq.ft., was defined so that under conditions of maximum gas flow the superficial velocity is approximately 20 ft./min. Weatherability data provided by the manufacturer indicated that the chemical resistivity of the 115 K and AA Fiberglas would be satisfactory under the service conditions. The depth and packing densities of the various strata were based upon the relationships discussed above and were selected to provide a maximum service life, a filtration efficiency in the order of 99.99% and a pressure drop of 4 in. of water at the rated air velocity.

It should be noted that the force necessary to compress large amounts of glass fibers may be considerable and will influence the structure of plant-scale containers. The resilience of the material requires that these forces be continually maintained. The necessary compressive force to restrain No. 115K Fiberglas to a given density, for example, is related to the packing density over the range of 1 to 9 lb./cu.ft. by the following expression:

$$C_f = 2.1(\rho_p - 0.6)^2 \qquad (11)$$

where

C_f = restraining compressive force, lb./sq.ft.

ρ_p = glass fiber packing density, lb./cu.ft.

To permit an evaluation of this vessel vent filter under actual service conditions, monitoring equipment was installed in a gallery adjacent to the process area (*12*). Aliquots of the upstream and downstream gases were drawn through the filter pressure lead lines through the canyon wall and passed through CWS Type 6 monitoring filters. The system used short, well-sloped lines and permitted reliable sampling. The data which were obtained with this apparatus are shown in Table 6.

In this efficiency range, with only approximately one part in ten thousand passing the filter, it is quite difficult to obtain definitive efficiency values. Even with the expedient of using different flow ratios through the two monitors it is difficult to obtain a set of monitoring filters for which the upstream sample is not too hot or the downstream sample too cold for accurate activity readings. Consequently, a majority of the efficiency determinations can be expressed only as "greater than" values. The data demonstrate, however, that the efficiency of the fiber glass bed is greater than 99.9% and probably near 99.99%. The efficiency values obtained agree well with the calculated design figures.

This filter unit has been in operation for more than three years. There have been no maintenance requirements nor has there been any change in the operating characteristics. Similarly, twelve other units of comparable design with air flow capacities of 200 to 20,000 cu.ft./min. have been exhibiting highly satisfactory operating performances during their service periods of one to three years.

Table 5.—Glass Fiber Vent Filter Formulation

Approximate superficial velocity—20 ft./min.

The gas stream contains varying amounts of submicron particles and acid vapors; the latter often reach a volume concentration as high as 50%.

Layer	Type Fiberglas	Packing Density (lb./cu.ft.)	Bed Depth (in.)	Initial Efficiency (%)	Initial Pressure Drop (in. of water)
Bottom	115K	1.5	12	39	0.10
Second	115K	3.0	10	53	0.24
Third	115K	6.0	20	93	1.34
Clean-up	AA	1.2	1	99.9	2.20
Total			43	99.99	4.0

Table 6.—Glass Fiber Filter Monitoring Data

Date	Upstream Monitor Flow (cu.ft./min.)	Upstream Monitor Actilvty (m.rep./hr.)	Downstream Monitor Flow (cu.ft./min.)	Downstream Monitor Activity (m.rep./hr.)	Efficiency (%)
12-19-50	1.0	6,000	1.0	<5	>99.92
12-19-50	1.0	1,500	1.0	<5	>99.67
12-21-50	1.0	4,250	1.0	<5	>99.88
12-21-50	1.0	33,000	1.0	8	99.97
12-21-50	0.5	9,750	1.5	<5	>99.98
12-22-50	0.5	6,000	3.0	<5	>99.98
12-22-50	0.5	135	3.0	<5	>99.39

The equations correlating the collection efficiency and pressure drop data suggest an alternate filter design which presents certain operational and economic advantages for large-scale installations that are not restricted by space limitations. Since the packing density exponent was determined to be 1.0 in the efficiency studies and 1.5 in the pressure drop studies, a freely packed bed of bulk fibers can be designed to provide a given forefilter efficiency at a lower pressure drop than that of a filter having graded layers at constant packing densities. In addition, the number of hold-down grids and therefore the overall cost of the installation may be reduced to a minimum. Such a unit, having an air-flow capacity of 125,000 cu.ft./min. and employing a freely packed bed of No. 115K Fiberglas as a forefilter in series with a separate clean-up unit of types B and AA Fiberglas, will be constructed at the Hanford Atomic Products Operation as part of the expansion program currently in progress. A greater collection efficiency, a lower flow resistance, and at least an equal service life are anticipated for the large-scale fibrous filter as compared to a sand filter at an estimated cost savings of approximately $500,000.

Summary

Fixed-bed filters formulated from fibrous glass media have been developed and selected at the Hanford Atomic Products Operation as the method best filling the requirements for the particulate decontamination of the process gas streams. The parameters affecting the dependent variables, collection efficiency, and flow resistance, have been thoroughly evaluated for the more promising glass fibers. A comparison of the useful filtration life to be expected from the various types of fibrous units has been made in a series of tests using a methylene blue aerosol. Based upon these data, plant scale equipment has been designed and installed to operate at a higher superficial air velocity than the plant sand filters with a greater efficiency, a lower flow resistance, and a greater life expectancy. The collection efficiency of the plant units has been determined to be about 99.99%. The first fibrous glass units have been in operation for over three years and there have been no maintenance requirements nor any significant change in the performance characteristics.

The use of glass fiber filters, of course, need not be restricted to the filtration of radioactive materials. Fixed-bed filters formulated with glass fibers can be advantageously employed whenever submicron particles, present in air streams at low concentrations, must be removed with a very high efficiency.

Acknowledgment

The authors wish to express their appreciation to the management of the General Electric Company and to the Atomic Energy Commission for permission to publish this paper.

Notation

- a = in Equation (8) constant empirically determined
- b = in Equation (8) constant empirically determined
- c = in Equation (8) constant empirically determined
- C = in Equation (8) constant, the dimensions of which are such that the decontamination factor is dimensionless
- Cf = restraining compressive force, lb./sq.ft.
- DF = decontamination factor
- K = constant in equation of Table 3.
- L = bed depth, in.
- M = constant in Equation (1)
- N = number of filter layers (comparable to transfer units)
- ΔP = pressure drop, inches of water
- V = superficial velocity, ft./min.
- W = weight rate of flow of particulate matter
- x = constant in equation of Table 3.
- y = constant in equation of Table 3.
- z = constant in equation of Table 3.

SUBSCRIPTS

- i = inlet conditions
- o = outlet conditions

GREEK LETTERS

- α = over-all fractional collection efficiency
- ρ_p = packing density, lb./cu.ft.
- Σ = cumulative grains of methylene blue passing to the filter layer per square foot of filter area

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dust collection

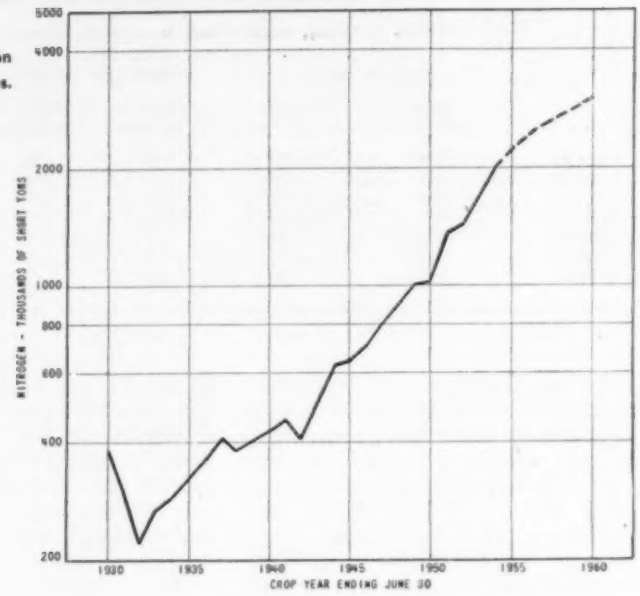

Fig. 1. Agricultural consumption of nitrogen in the United States.

economics of ammonia manufacture from several raw materials

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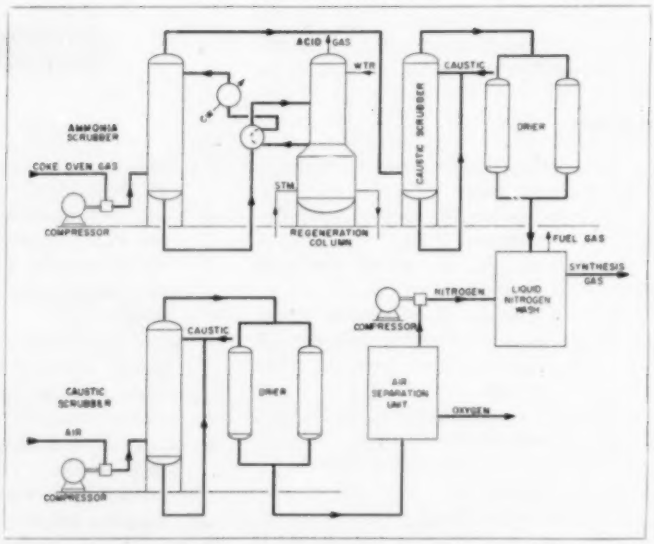

Figure 2 is a typical flow scheme for processing coke-oven gas. Unlike the partial oxidation cases, coke-oven gas initially contains a large percentage of molecular hydrogen and therefore needs only to be purified. A typical coke-oven gas may contain from 50 to 60% hydrogen, for example, in a mixture of light hydrocarbons with small amounts of sulfur and oxygen compounds. The coke-oven gas is compressed to about 350 lb./sq.in. and scrubbed with weak ammonia solution for carbon dioxide and hydrogen sulfide removal. An ammonia solution is preferable to amine because of certain organic sulfur and nitrogen compounds in coke-oven gas which form non-heat-regenerable compounds with the amines. The ammonia solution is regenerated by the application of heat. Final carbon dioxide removal is accomplished by caustic scrubbing. Separation and recovery of the hydrocarbons is carried out in a low-temperature nitrogen wash unit similar to that used in the partial-oxidation process. Methane, ethylene, ethane, and heavier hydrocarbons can be recovered separately if desired. The nitrogen is supplied from an air liquefaction unit as in the partial oxidation case, except that the oxygen is usually produced at a lower purity as it is not required by the process.

In 1887 Thomas Henry Huxley, the English biologist, gloomily forecast the end of western civilization within 50 years due to the exhaustion of available fixed nitrogen. Fritz Haber and 50 million tons of fixed nitrogen in the form of synthetic ammonia have denied the realization of Huxley's prediction, but the tacit problem is nevertheless continuing and real. In the United States, for example, during the 20-year interval between 1930 and 1950 a population increase of 28 million was absorbed without an appreciable change in agricultural acreage. This was a period of enlightened farming—increased use of mechanized equipment, hybrid corn, crop rotation, erosion control, and a greatly increased production of vegetable protein in the form of the soybean. Undoubtedly advances in farming techniques will increase the productivity of American farmland still further, but will improved techniques permit the feeding and clothing of another increment of 28 million people due in the next 10 years?

The key to the solution is the availability of essential plant nutrients, par-

ticularly nitrogen, in the soil. The crop yield from exhausted land, for example, can frequently be increased two- to threefold by the use of nitrogenous fertilizers. Figure 1 indicates that the farmer is aware of this method of increasing the productivity of his land. From 410,000 short tons of nitrogen in 1940, agricultural consumption in the United States jumped to 1 million tons in 1950 and 2.2 million tons in 1954. And the 1960 estimated demand exceeds 3 million tons/year.

Agriculture is approximately 70% of the ammonia story. The remaining 30% has interesting facets also. The increased production of synthetic fibers, for example, has been accompanied by a proportional increase in ammonia consumption. Urea plastics, aniline dyes, and organic nitrogen compounds such as the amines have been in much greater demand.

From the foregoing, it is apparent that the manufacture of synthetic ammonia in the United States has increased rapidly during the past 10 years. It is also indicated that the demand will continue to increase in the next few years, surpassing the industry's present production capacity. How will industry meet this increased demand for ammonia? To answer this logically, one must first look at the various routes by which ammonia can be manufactured.

The synthesis of ammonia consists of reacting three volumes of hydrogen with one volume of nitrogen. Nitrogen in most commercial processes is obtained from the air. Hydrogen, either pure or mixed with other gases, may be available as a by-product from other processes or can be manufactured from the various hydrocarbons. In any event, the cost of obtaining hydrogen in a form suitable for ammonia synthesis is the most important variable in the economics of ammonia manufacture.

The purpose of this paper is to compare the costs of manufacturing ammonia with hydrogen obtained from natural gas, from residual oils, from coal, from coke-oven gas, and from refinery catalytic-reformer off-gas. It is not an object of the present work to compare different processes for manufacturing ammonia; rather, a single process scheme of synthesis-gas preparation, purification, and synthesis has been employed in the three cases of hydrocarbon feed, and a similar purification and synthesis scheme has been used in the two cases of hydrogen-rich by-product gases. Briefly, the complete process scheme involves the following steps:

(1) Separation of air into nitrogen and oxygen; (2) partial oxidation of hydrocarbons to produce carbon monoxide and hydrogen; (3) reaction of carbon monoxide with water to produce additional hydrogen; (4) purification of the

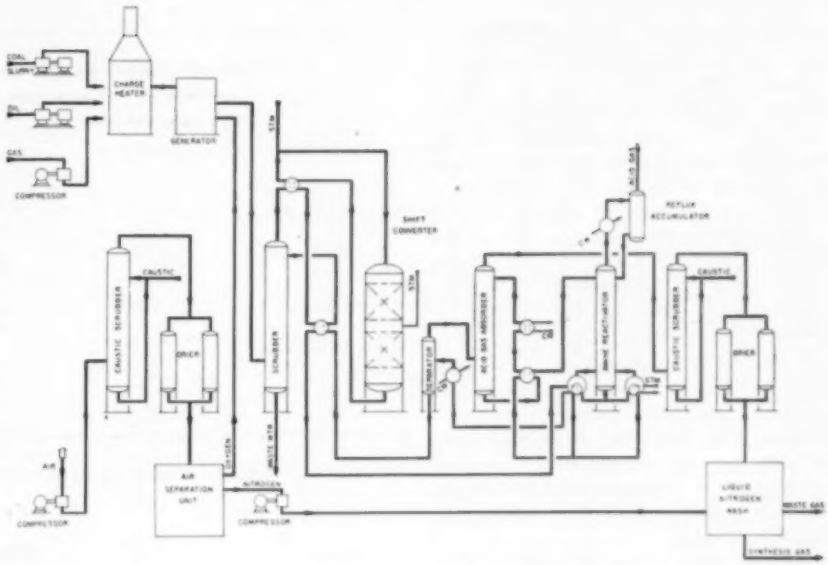

Figure 3 is a typical flow scheme for the production of synthesis gas by the partial oxidation of gas, oil, or coal. Compressed air is scrubbed with caustic for carbon dioxide removal and then dried. The air is then separated by liquefaction into oxygen of 95% purity and nitrogen of 99.99% purity. The hydrocarbon feed is preheated and partially oxidized with oxygen from the air-separation plant. The combustion products from the generator, consisting mainly of carbon monoxide and hydrogen, are charged to the shift converter where the carbon monoxide is converted to carbon dioxide with the production of 1 mole of hydrogen/mole of carbon monoxide converted. The water required by this reaction is provided by saturation of the gas in the water scrubber plus the addition of some steam. After conversion most of the carbon dioxide is removed by absorption in monoethanolamine. The hot effluent stream from the shift converter is used to supply part of the heat of regeneration of the monoethanolamine, thus reducing the amount of steam required. Final cleanup of carbon dioxide is accomplished by scrubbing with caustic. The hydrogen stream then contains only a small percentage of carbon monoxide and methane, which is removed by condensation with liquid nitrogen in a low-temperature unit. Part of the synthesis nitrogen is supplied by vaporization of liquid nitrogen in the nitrogen-wash unit. Additional nitrogen from the air-liquefaction plant is added to the hydrogen to make the synthesis-gas mixture of 3 parts hydrogen and 1 part nitrogen. The mixture at this point contains less than 100 p.p.m. argon and less than 20 p.p.m. oxygen compounds.

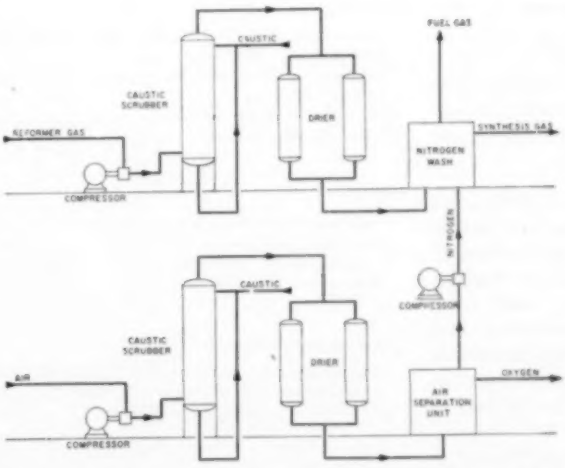

Figure 4 is a typical flow scheme for the processing of by-product gas from a petroleum catalytic-reforming operation. A high hydrogen-content gas, such as might be obtained from a platinum-catalyst unit, has been assumed here to provide a case distinct from the coke-oven gas case. In view of the high hydrogen concentration and low acid-gas concentration, the purification of this reformer gas is very easily accomplished by a light caustic scrub and a liquid nitrogen wash. Again nitrogen for the purification unit and for the synthesis mixture is supplied from a standard air-liquefaction unit. In either the reformer-gas or coke-oven–gas case, oxygen of 85% purity is available as a by-product, but in this study this oxygen will be treated as a waste gas.

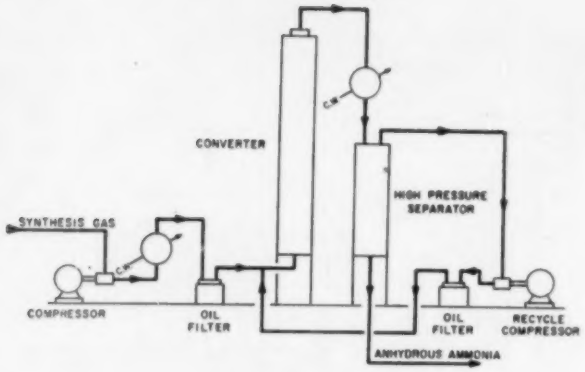

Fig. 5. Typical process flow scheme for the synthesis of ammonia from a mixture of pure hydrogen and nitrogen.

hydrogen; and (5) synthesis of ammonia from the hydrogen and nitrogen mixture. In the coke-oven gas and reformer gas cases, the hydrogen is present initially; therefore steps (2) and (3) are omitted.

The synthesis-gas mixture produced by each of the five routes shown in Figures 2, 3, and 4 is the same—3 parts hydrogen, 1 part nitrogen, about 100 p.p.m. inerts, and less than 20 p.p.m. total oxygen-containing impurities. As shown in Figure 5, the synthesis-gas mixture is compressed to about 600 atm. and filtered for oil removal. At the inlet to the ammonia converter, the fresh feed is joined by a recycle stream of unconverted hydrogen and nitrogen. The combined feed stream is heated inside the ammonia converter by heat exchange with the product gases. The hot hydrogen-nitrogen mixture passes through a bed of promoted iron catalyst, where conversion to ammonia occurs. Effluent gases from the converter are cooled by exchange with water, and product ammonia is condensed and separated from the unconverted gases in a high-pressure separator. The ammonia is sent directly to storage and the hydrogen and nitrogen are recycled by means of the recycle compressor.

The operating requirements for the five cases are summarized in Table 1. The consumptions shown are based on a complete operating unit including cooling tower, steam generators, product storage, and electrical substation. All compressors are gas driven.

The quantities shown in Table 1 are based on the following analyses: (1) natural gas composition, in mole %, with a gross heating value of 1,040 B.t.u./std.cu.ft.—CH_4, 92; C_2+, 6; N_2, 1; CO_2, 1; (2) fuel-oil quantities, based on a 9° A.P.I. Bunker C and a gross heating value of 18,200 B.t.u./lb., with the following ultimate analysis in weight %—carbon, 88.3; hydrogen, 9.3; sulfur, 1.1; ash, 1.3; (3) coal quantities, with a gross heating value of 12,600 B.t.u./lb., analyzed in weight % as carbon, 70.4; hydrogen, 4.8; nitrogen, 1.4; oxygen, 5.8; sulfur, 1.8; ash, 14.8; moisture, 1.0; and (4) coke-oven–gas tabulation, with a gross heating value of 582 B.t.u./std.cu.ft. based on the following volume % analysis—hydrogen, 55; carbon monoxide, 5; hydrocarbons, 33; nitrogen and oxygen, 5; acid gases, 2.

Table 1.—Operating Requirements for Ammonia Manufacture

Per ton of ammonia

	Natural gas	Fuel oil	Coal	Coke oven gas	Reformer gas
Gas feed, 1,000 std.cu.ft.	26.0	....	....	127	75.7
Oil feed, bbl.	....	4.27	....	....	....
Coal feed, tons	....	....	1.28	....	....
Shift catalyst, lb.	0.30	0.35	0.35	....	....
Synthesis catalyst, lb.	0.50	0.50	0.50	0.50	0.50
Caustic, lb.	8.0	8.0	8.0	6.0	5.5
Monoethanolamine, lb.	0.30	0.40	0.40	....	....
Lube oil, gal.	0.5	0.5	0.5	0.6	0.5
Fuel gas, million B.t.u.*	22.0	12.0	14.2	—36.7†	—4.2†
Fuel oil, bbl.	....	2.54	....	....	....
Fuel coal, tons	....	....	0.56	....	....
Electricity, kw.-hr.	108	120	125	100	80
Treated water, 1,000 gal.	1.07	1.36	1.50	1.16	....
Raw water, 1,000 gal.	4.5	5.0	5.0	3.2	2.2
Operators/shift	7	7	7	6	5

* Based on gas-driven compressors.
† Includes credit for recovered hydrocarbon gases.

Table 2.—Manufacturing Cost of Ammonia from Natural Gas

	in dollars/ton	
Tons/stream day	100	200
Capital investment	$3,950,000	$6,843,000
Materials		
Natural-gas feed, 31.2¢/1,000 std.cu.ft.(30¢/million B.t.u.)	8.11	8.11
Shift catalyst, 72¢/lb.	0.22	0.22
Synthesis catalyst, 60¢/lb.	0.30	0.30
Caustic, 3¢/lb.	0.24	0.24
Monoethanolamine, 26¢/lb.	0.08	0.08
Lube oil, 80¢/gal.	0.40	0.40
	9.35	9.35
Utilities		
Fuel gas, 30¢/million B.t.u.	6.60	6.60
Electricity, 0.8¢/kw.-hr.	0.86	0.86
Treated water, 13¢/1,000 gal.	0.14	0.14
Raw water, 5¢/1,000 gal.	0.23	0.23
	7.83	7.83
Other operating expenses		
Operating labor, $2.25/man-hr. + 22% payroll burden *	4.85†	2.43†
Maintenance, 4% of capital investment ‡	4.55	3.94
Plant general, 40% of total labor **	3.03	1.92
	12.43	8.29
Fixed charges		
Depreciation, 10%	11.38	9.86
Taxes, interest, insurance, 6%	6.83	5.92
	18.21	15.78
Sum of variable manufacturing costs	$47.82	$41.25

Table 3.—Manufacturing Cost of Ammonia from Fuel Oil

in dollars/ton

Tons/stream day	100	200
Capital investment	$4,098,000	$7,084,000
Materials		
Fuel oil, $1.92/bbl. (30¢/million B.t.u.)	8.20	8.20
Shift catalyst, 72¢/lb.	0.25	0.25
Synthesis catalyst, 60¢/lb.	0.30	0.30
Caustic, 3¢/lb.	0.24	0.24
Monoethanolamine, 26¢/lb.	0.10	0.10
Lube oil, 80¢/gal.	0.40	0.40
	9.49	9.49
Utilities		
Fuel gas, 30¢/million B.t.u.	3.60	3.60
Fuel oil, $1.92/bbl.	4.88	4.88
Electricity, 0.8¢/kw.-hr.	0.96	0.96
Treated water, 13¢/1,000 gal.	0.18	0.18
Raw water, 5¢/1,000 gal.	0.25	0.25
	9.87	9.87
Other operating expenses		
Operating labor, $2.25/man-hr. + 22% payroll burden *	4.85†	2.43†
Maintenance, 4% of capital investment ‡	4.73	4.08
Plant general, 40% of total labor **	3.08	1.95
	12.66	8.46
Fixed charges		
Depreciation, 10%	11.82	10.21
Taxes, interest, insurance, 6%	7.09	6.13
	18.91	16.34
Sum of variable manufacturing costs	$50.93	$44.16

Table 4.—Manufacturing Cost of Ammonia from Coal

in dollars/ton

Tons/stream day	100	200
Capital investment	$4,248,000	$7,344,000
Materials		
Coal feed, $7.56/ton (30¢/million B.t.u.)	9.68	9.68
Shift catalyst, 72¢/lb.	0.25	0.25
Synthesis catalyst, 60¢/lb.	0.30	0.30
Caustic, 3¢/lb.	0.24	0.24
Monoethanolamine, 26¢/lb.	0.10	0.10
Lube oil, 80¢/gal.	0.40	0.40
	10.97	10.97
Utilities		
Fuel gas, 30¢/million B.t.u.	4.26	4.26
Fuel coal, $7.56/ton	4.23	4.23
Electricity, 0.8¢/kw.-hr.	1.00	1.00
Treated water, 13¢/1,000 gal.	0.20	0.20
Raw water, 5¢/1,000 gal.	0.25	0.25
	9.94	9.94
Other operating expenses		
Operating labor, $2.25/man-hr. + 22% payroll burden *	4.85†	2.43†
Maintenance, 4% of capital investment ‡	4.90	4.24
Plant general, 40% of total labor **	3.12	1.99
	12.87	8.66
Fixed charges		
Depreciation, 10%	12.25	10.59
Taxes, interest, insurance, 6%	7.35	6.35
	19.60	16.94
Sum of variable manufacturing costs	$53.38	$46.51

The following applies to Tables 2, 3, and 4.

* Payroll burden covers vacations, insurance, and benefits.
† Adjusted for 95% operating factor.
‡ Maintenance is 60% labor, 40% material.
** Typical, including nonoperating service and administrative personnel up to and including plant manager.

The catalytic-reformer gas is assumed to have come from a fixed-bed, nonregenerable platinum-catalyst unit, because it is desired to show a case with high-hydrogen-content gas; whereas gas from a molybdenum-catalyst unit would correspond closely to coke-oven gas. The analysis of the gas from the platinum-catalyst unit is as follows: hydrogen, 93.0 and hydrocarbons, 7.0 vol. %. The gross heating value is 490 B.t.u./std.cu.ft.

In the coke-oven– and reformer-gas cases, credit is taken for fuel gas recovered from the hydrogen stream in the low-temperature unit.

By use of the operating requirements given in Table 1 and of typical costs and investments, comparisons have been made for plants designed for capacities of 100 and 200 tons/stream day of anhydrous ammonia. The costs shown include operating offsite facilities such as steam generators, cooling tower, refrigerated storage spheres for 10 days' production, and electrical substation. A synthesis-catalyst-cartridge-change and repair house is included. The costs shown cover all variable investment costs and therefore do not include such items as land, fencing, administration building, maintenance shops (other than the cartridge house), roads, and rail sidings, which are essentially the same for each of the cases considered.

economics

In the selection of values for the feed streams, a common denominator of 30 cents/million B.t.u. gross heating value was chosen. Natural gas is valued at 31.2 cents/1,000 std.cu.ft., residual oil at $1.92/barrel, coal at $7.56/ton, coke-oven gas at 17.5 cents/1,000 std.cu.ft., and reformer gas at 14.7 cents/1,000 std. cu.ft. A set of typical energy costs is thus achieved that can be adjusted to reflect other local situations in which one raw material might have an initial cost advantage over another.

In Table 2, costs of manufacturing ammonia from natural gas are shown. The unit costs shown for materials, utilities, and other expenses are typical values applicable in several areas of this country. The material and utility consumptions shown are the same for the two plant sizes because variations in efficiencies are very slight.

Table 3 illustrates the costs of ammonia from fuel oil on the same basis as the costs for natural gas. Tables 4, 5, and 6 likewise represent the costs of

Table 5.—Manufacturing Cost of Ammonia from Coke-Oven Gas

in dollars/ton

Tons/stream day	100	200
Capital investment	$3,620,000	$6,231,000
Materials		
Coke-oven gas feed, 17.5¢/1,000 std.cu.ft.(30¢/million B.t.u.)	22.22	22.22
Synthesis catalyst, 60¢/lb.	0.30	0.30
Caustic, 3¢/lb.	0.18	0.18
Lube oil, 80¢/gal.	0.48	0.48
	23.18	23.18
Utilities		
Fuel gas, 30¢/million B.t.u.	—11.01	—11.01
Electricity, 0.8¢/kw.-hr.	0.80	0.80
Treated water, 13¢/1,000 gal.	0.15	0.15
Raw water, 5¢/1,000 gal.	0.16	0.16
	—9.90	—9.90
Other operating expenses		
Operating labor, $2.25/man-hr. + 22% payroll burden *	4.16†	2.08†
Maintenance, 4% of capital investment ‡	4.17	3.59
Plant general, 40% of total labor **	2.66	1.69
	10.99	7.36
Fixed charges		
Depreciation, 10%	10.43	8.98
Taxes, interest, insurance, 6%	6.26	5.39
	16.69	14.37
Sum of variable manufacturing costs	$40.96	$35.01

Table 6.—Manufacturing Cost of Ammonia from Catalytic-Reformer Gas

in dollars/ton

Tons/stream day	100	200
Capital investment	$2,980,000	$5,106,000
Materials		
Reformer gas feed, 14.7¢/1,000 std.cu.ft.(30¢/million B.t.u.)	11.13	11.13
Synthesis catalyst, 60¢/lb.	0.30	0.30
Caustic, 3¢/lb.	0.17	0.17
Lube oil, 80¢/gal.	0.40	0.40
	12.00	12.00
Utilities		
Fuel gas, 30¢/million B.t.u.	—1.26	—1.26
Electricity, 0.8¢/kw.-hr.	0.64	0.64
Raw water, 5¢/1,000 gal.	0.11	0.11
	—0.51	—0.51
Other operating expenses		
Operating labor, $2.25/man-hr. + 22% payroll burden *	3.46†	1.73†
Maintenance, 4% of capital investment ‡	3.44	2.94
Plant general, 40% of total labor **	2.21	1.40
	9.11	6.07
Fixed charges		
Depreciation, 10%	8.59	7.36
Taxes, interest, insurance, 6%	5.15	4.42
	13.74	11.78
Sum of variable manufacturing costs	$34.34	$29.34

The following applies to Tables 5 and 6.

* Payroll burden covers vacations, insurance, and benefits.
† Adjusted for 95% operating factor.
‡ Maintenance is 60% labor, 40% material.
** Typical, including nonoperating service and administrative personnel up to and including plant manager.

ammonia from coal, coke-oven gas, and reformer gas.

A recapitulation of the investment and manufacturing costs for the five raw materials is shown in Table 7. The first two columns are capital costs for 100 and 200 tons/stream day plants in thousands of dollars. The second two columns summarize the manufacturing costs for the same cases on the basis of the selected fuel costs. The reformer-gas case is the cheapest in investment and manufacturing costs, and the partial oxidation of coal is the most expensive. However, it must be emphasized that local variations in raw-material costs could influence the manufactured costs by as much as $7 or $8 in some cases.

In summary, typical investment and manufacturing costs for the manufacture of ammonia from natural gas, residual oil, coal, coke-oven gas, and petroleum reformer off-gas have been presented. Unit-operating requirements have been presented in a manner to facilitate the use of these data to study the manufacturing costs under other local price conditions.

Acknowledgment

The author wishes to acknowledge the valuable assistance given by members of the Engineering Division of The Fluor Corporation, Ltd., and to thank The Fluor Corporation, Ltd., for permission to publish this paper.

Presented at the ninth annual one-day meeting of the South Texas Local Section, Galveston, Texas.

Table 7.—Recapitulation of Investment and Manufacturing Costs

	Capital investment in thousands of dollars	
Tons/stream day	100	200
Natural gas	3,950	6,843
Fuel oil	4,098	7,084
Coal	4,248	7,344
Coke-oven gas	3,620	6,231
Reformer gas	2,980	5,106

	Sum of variable manufacturing costs, dollars/ton	
Tons/stream day	100	200
Natural gas	47.82	41.25
Fuel oil	50.93	44.16
Coal	53.38	46.51
Coke-oven gas	40.96	35.01
Reformer gas	34.34	29.34

flow capacities of sieve-plate liquid-extraction columns

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Flow capacities for nine liquid systems were studied in a 2.75- and a 1.33-in. I. D. sieve-plate extraction column with orifice diameters of 0.0938 and 0.126 in. Empirical correlations have been derived which make it possible to predict the capacities of sieve-plate columns from the physical properties of the liquids. The correlations obtained in this investigation have been found to be valid over the following ranges of variables: interfacial tension, 4.4 to 41 dynes/cm.; dispersed-phase viscosity, 0.246 to 3.29 centipoises; continuous-phase viscosity, 0.87 to 7.61 centipoises; orifice diameter, 0.0938 to 0.128 in.; differential density, 7.9 to 36.4 lb./cu. ft.; free area, 0.12 to 7.8%.

Several investigators have presented data on flow capacities of sieve-plate liquid-extraction columns. Major (*3*) showed that the capacity of a column may be expressed in terms of an over-all orifice coefficient, coefficients being obtained for the system acetic acid–ethyl ether–water for orifice diameters of 0.096, 0.111, and 0.128 in. in a 1.75-in. I.D. column. Pyle, Colburn, and Duffey (*4*) presented data on the same system with orifice diameters of 0.0635, 0.110, and 0.201 in. in a column 8.63 in. I.D. Other investigators (*2, 5*) have also expressed capacity data in terms of varying orifice coefficients.

The principal disadvantage of expressing column capacity in terms of varying orifice coefficients is that it is difficult to predict the capacity of a column containing liquid systems for which coefficients have not been already established. Bussolari, Schiff, and Treybal (*1*) have presented a design method applicable to any system in which certain physical properties of the liquids are known. They outline procedures for calculating the individual effects of interfacial tension, orifice effect, and frictional effects in the downspout. The present paper deals primarily with the interfacial tension and orifice effects and presents data for nine different liquid systems covering a wide range of interfacial tension, differential density, and viscosity. A design method is proposed which is believed to be an improvement over any of the previous methods.

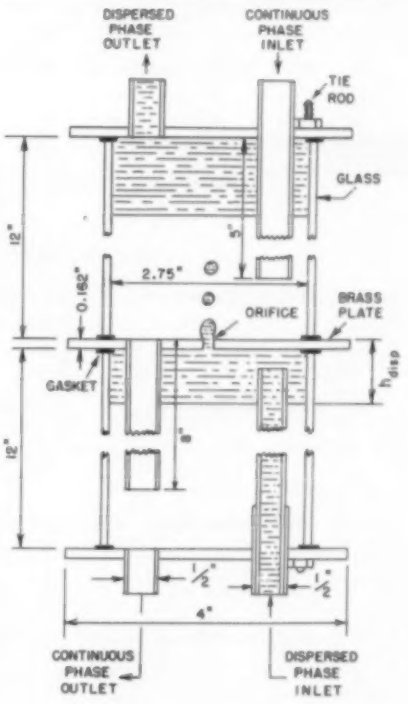

Fig. 1. Sieve-plate column.

Apparatus

The apparatus consisted essentially of a glass column of circular cross section equipped with a sieve plate containing one orifice and a downspout, as shown in Figure 1. The column consisted of two sections of 3-in. O.D. glass tubing

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Table 2.—Experimental Data

Series	System	Orifice diam., d_o, in.	Orifice velocity, U_o, ft./sec.	Interface depth, h_{diff}, in.*	$\left(\frac{\Delta\rho}{\rho_D}\right)h$	Reynolds number, Re	Orifice Coefficient: Over-all, C	Orifice Coefficient: Corrected, C_o
1.	Benzene–water	0.126	0.202	0.61	0.0161	300	0.29	0.69
			0.700	1.65	0.153	1040	0.62	0.74
			0.991	2.80	0.321	1470	0.67	0.74
			1.34	4.40	0.555	1980	0.72	0.77
			1.64	6.30	0.832	2430	0.74	0.77
2.	Benzene–water	0.0938	0.268	0.91	0.0234	295	0.32	0.76
			0.513	1.42	0.0920	565	0.49	0.71
			0.996	2.99	0.321	1100	0.65	0.75
			1.44	5.15	0.636	1590	0.72	0.78
			1.78	7.25	0.943	1960	0.75	0.79
3.	n-Heptane–water	0.126	0.189	0.41	0.0116	300	0.21	0.76
			0.717	0.83	0.174	1135	0.55	0.74
			1.17	1.52	0.441	1850	0.66	0.76
			1.35	1.91	0.592	2140	0.68	0.75
			2.20	4.15	1.46	3490	0.75	0.79
4.	n-Heptane–water	0.0938	0.349	0.57	0.0387	410	0.32	0.77
			0.670	0.85	0.147	790	0.50	0.75
			1.14	1.57	0.425	1345	0.63	0.76
			1.62	2.70	0.862	1910	0.68	0.75
			2.15	4.21	1.45	2540	0.73	0.77
5.	Ethyl ether–water	0.126	0.857	0.68	0.212	2440	0.74	0.80
			1.10	1.06	0.352	3140	0.76	0.80
			1.49	1.91	0.663	4240	0.77	0.79
			1.71	2.52	0.885	4770	0.77	0.79
			2.03	3.44	1.22	5780	0.78	0.79
6.	Ethyl ether–water	0.0938	0.735	0.53	0.146	1550	0.72	0.83
			0.848	0.71	0.212	1780	0.72	0.79
			1.403	0.97	0.308	2200	0.76	0.81
			1.72	2.34	0.812	3640	0.80	0.82
			2.17	3.66	1.29	4570	0.81	0.82
7.	Water–carbon tetrachloride	0.126	0.634	0.39	0.122	725	0.57	0.78
			0.789	0.51	0.192	900	0.62	0.78
			1.207	0.91	0.426	1380	0.71	0.80
			1.818	1.85	0.973	2080	0.76	0.80
			2.27	2.78	1.52	2600	0.77	0.78
8.	Isobutyl alcohol–water	0.126	0.344	0.43	0.0468	105	0.54	0.69
			0.666	1.22	0.183	205	0.63	0.67
			1.28	3.66	0.606	395	0.70	0.71
			1.42	4.40	0.735	440	0.70	0.72
			1.72	6.22	1.05	535	0.72	0.73
9.	Isobutyl alcohol–water	0.0938	0.288	0.42	0.0346	67	0.46	0.66
			0.539	1.04	0.142	125	0.55	0.62
			1.07	3.05	0.490	245	0.64	0.66
			1.46	5.20	0.863	335	0.67	0.69
			1.81	7.47	1.254	420	0.69	0.70
10.	Amyl alcohol–water	0.126	0.370	0.50	0.0618	91	0.50	0.64
			0.597	0.94	0.152	146	0.59	0.66
			0.940	1.89	0.348	230	0.65	0.69
			1.31	3.37	0.653	320	0.68	0.70
			1.71	5.40	1.07	418	0.70	0.71
11.	Amyl alcohol–water	0.0938	0.244	0.39	0.0288	44	0.37	0.62
			0.472	0.81	0.115	86	0.50	0.60
			0.780	1.63	0.284	142	0.58	0.63
			1.55	4.90	0.957	280	0.67	0.68
			1.85	6.89	1.37	335	0.67	0.68
12.	Naphtha–water	0.0938	0.462	0.53	0.0575	675	0.41	0.83
			0.868	0.96	0.248	1260	0.58	0.76
			1.69	2.28	0.830	2460	0.73	0.80
			2.38	3.97	1.58	3470	0.78	0.81
			2.58	4.72	1.91	3760	0.78	0.81
13.	Naphtha plus oil–water	0.0938	0.226	0.49	0.0266	71	0.26	0.60
			0.561	0.91	0.150	177	0.47	0.63
			0.886	1.67	0.375	280	0.55	0.63
			1.61	3.66	0.962	508	0.67	0.71
			2.22	6.04	1.66	700	0.72	0.75
14.	Toluene–water	0.126	0.405	0.75	0.0504	612	0.50	0.78
			0.829	1.54	0.183	1250	0.71	0.84
			0.941	1.89	0.242	1420	0.73	0.83
			1.36	3.43	0.501	2050	0.78	0.84
			1.50	4.06	0.607	2270	0.79	0.84

* All interface depths were measured from the top surface of the plate to the interface below the plate.

⅛ in. thick and 12 in. long. The top, bottom, and orifice plates were constructed of brass stock 4 in. square and 0.162 in. thick. Two interchangeable orifice plates were used in this investigation, one plate having an orifice diameter of 0.0938 in. and the other of 0.126 in. The column was held in alignment by four brass tie rods 26 in. long and 3/16 in. in diam.

A metal ruler was used to measure the depth of the light liquid under the orifice plate. A 500-ml. graduated cylinder and a stop watch were used to measure the rate of flow of the dispersed phase.

This apparatus was used for series 1 to 13, inclusive. In series 14 the apparatus was essentially the same as for the other runs except that the column diameter was 1.33 in. I.D.

Materials

The solvents were all of a technical grade, no attempt having been made toward further purification. The water came from the laboratory distilled-water tap. For each system studied, the continuous and dispersed phases were saturated with each other before being used in the column. The density of each phase was measured with a Westphal balance, the viscosity was measured with an Ostwald viscometer, and the interfacial tension was measured with a Du Nouy tensiometer. The physical properties of the nine pairs of liquids covered in this study are presented in Table 1.

Procedure

At the start of a run, the column was first filled with the continuous phase, and then the dispersed phase was allowed to enter the bottom of the column, its rate of flow being controlled by a stopcock in the feed line. When the interface under the orifice plate reached a constant level, its reading was taken and the corresponding rate of flow was measured by recording the time required to collect a given volume of the dispersed phase in a graduated cylinder.

As the primary purpose of this investigation was to study the fluid-flow characteristics in terms of physical properties, all experiments were conducted with pairs of essentially immiscible liquids in which no solute was present. No actual extraction took place, and the physical properties of the liquids therefore did not change in passing through the column.

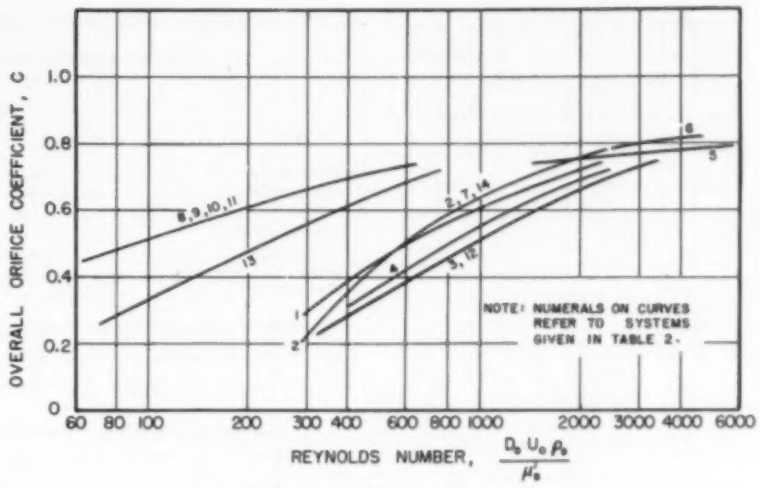

Fig. 2. Over-all orifice coefficients.

Frictional effects in the downspout were not studied in this investigation because all runs were conducted with the continuous phase remaining stationary; that is, the flow of liquid through the downspout was zero.

Correlation of Data

OVER-ALL COEFFICIENTS

It has been shown previously (*1*) that the total depth of light liquid below the plate consists of the sum of the separate effects of the dispersed and continuous liquids:

$$h_t = h_{disp} + h_{cont} \qquad (1)$$

The quantity h_{cont} was equal to zero in this investigation, as the continuous liquid was stationary in all cases. The original experimental data covered more than three hundred separate rates of flow, a representative portion of which appears in Table 2.

Over-all orifice coefficients were calculated by means of the equation

$$C = \frac{U_o}{\sqrt{2g\left(\frac{\Delta\rho}{\rho D}\right)\frac{h_{disp}}{12}}} \qquad (2)$$

It will be noted that the velocity of approach has been neglected because it introduces only a very small error.

In Figure 2 the over-all orifice coefficient C is plotted against Reynolds number for each of the systems studied. The over-all coefficient varies not only with the Reynolds number but also with the particular system under consideration.

extraction

CORRECTED COEFFICIENTS

Plotting h_{disp} against the square of the velocity of the dispersed phase U_o^2 gives a straight line for each of the systems studied. A typical plot is shown in Figure 3 for the benzene-water system with an 0.126-in. orifice. The intercept is designated as h' and represents the

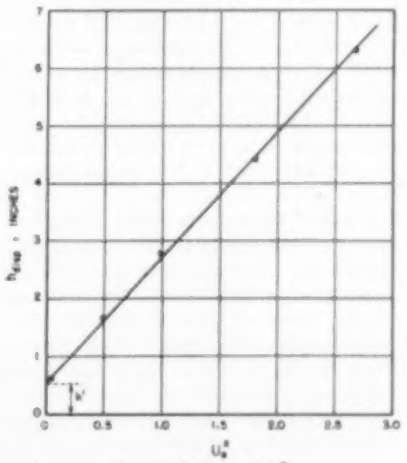

Fig. 3. h_{disp} vs. U_o^2.

Table 1.—Physical Properties of Systems Studied

Liquids used		Temperature	Density, lb./cu.ft.		Viscosity, centipoises		Interfacial tension, σ,
Dispersed	Continuous	°C.	ρ_D	ρ_C	μ_D	μ_C	dynes/cm.
Benzene	Water	27	54.4	62.3	0.573	0.88	28
n-Heptane	Water	27	45.0	62.3	0.444	0.88	41
Ethyl ether	Water	24	44.8	61.2	0.246	1.19	12
Water	Carbon Tetrachloride	27	62.3	98.7	0.853	0.93	41
Isobutyl alcohol	Water	26	52.6	61.7	2.65	1.17	4.4
Amyl alcohol	Water	26	51.5	62.1	3.29	0.97	7.5
Naphtha	Water	24	43.3	62.4	0.346	0.88	41
Naphtha + oil	Water	26	48.1	62.3	1.77	0.87	16
Toluene	Water	27	53.2	62.1	0.55	0.89	23

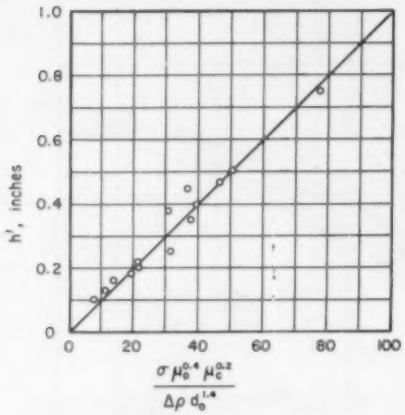

Fig. 4. Experimental values of h'.

depth obtained by extrapolating to zero flow of the dispersed phase. Values of h' were determined for each system by making plots similar to Figure 3. An empirical correlation was developed which relates h' to the orifice diameter and certain physical properties of the liquids as shown in the equation:

$$h' = \frac{0.01\sigma\mu_D^{0.4}\mu_C^{0.2}}{\Delta\rho d_o^{1.4}} \qquad (3)$$

Equation (3) is shown as the solid line in Figure 4. The points on this graph represent the intercept values obtained from plots of h_{disp} vs. U_o^2. Equation (3) may be used to predict the value of h' for any system in which the necessary physical properties and orifice diameter are known. The authors wish to emphasize that Equation (3) is an empirical relation and is not meant to represent the true mechanism of the drop-formation process. It has been found applicable to the nine different liquid systems of this investigation as well as the four systems studied by Bussolari et al. (*1*), covering the following ranges of variables: interfacial tension, 4.4 to 41 dynes/cm.; dispersed-phase viscosity, 0.246 to 3.29 centipoises; continuous-phase viscosity, 0.87 to 7.61 centipoises; orifice diameter, 0.0938 to 0.128 in.; differential density, 7.9 to 36.4 lb./cu. ft.; free area, 0.12 to 7.8%. It was not possible to check the work of other investigators owing to the lack of complete physical data on the systems they used.

During the experiments it was observed that whenever the column was started up, a certain minimum depth was required to initiate flow of the dispersed phase. However, once flow was started, it was possible to maintain flow at interface depths less than those at which flow was initiated. As the flow rate was decreased, a certain minimum depth was obtained at which flow through the orifice stopped. This minimum depth

Table 3.—Observed and Intercept Values of h'

System	Orifice diam., in.	h', in. Observed	Intercept *
Benzene–water	0.126	0.59	0.50
Benzene–water	0.0938	0.86	0.75
n-Heptane–water	0.126	0.39	0.38
n-Heptane–water	0.0938	0.51	0.47
Naphtha–water	0.0938	0.43	0.40
Naphtha plus oil–water	0.0938	0.41	0.40
Toluene–water	0.126	0.47	0.45

* Intercept obtained from a plot of h_{disp} vs. U_o^2.

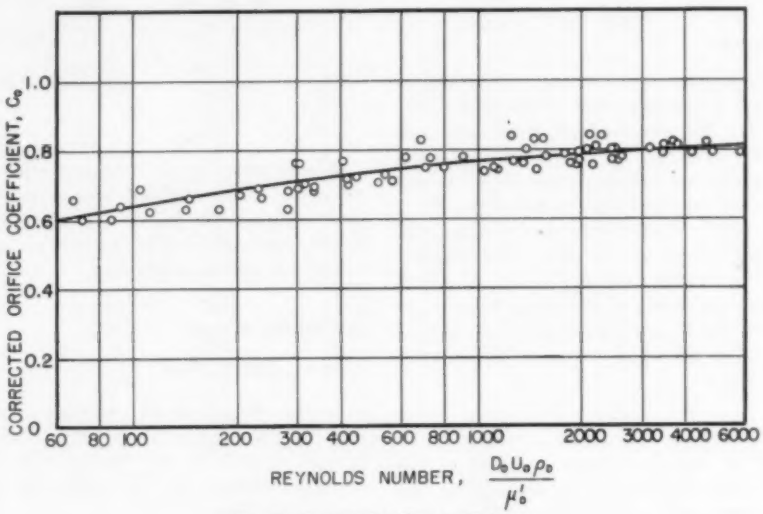

Fig. 5. Corrected orifice coefficients.

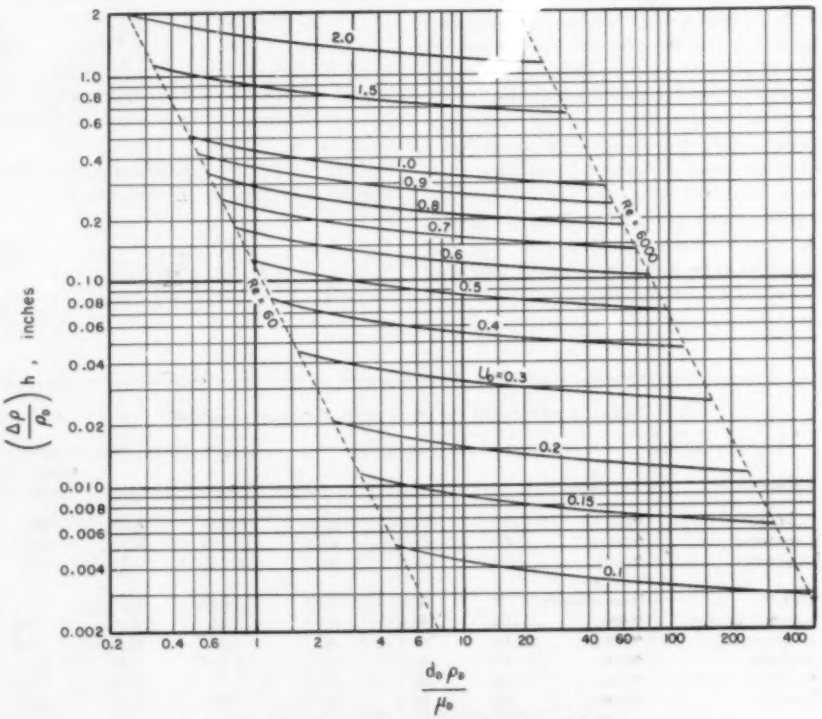

Fig. 6. Chart for solution of Equations (4) and (5).

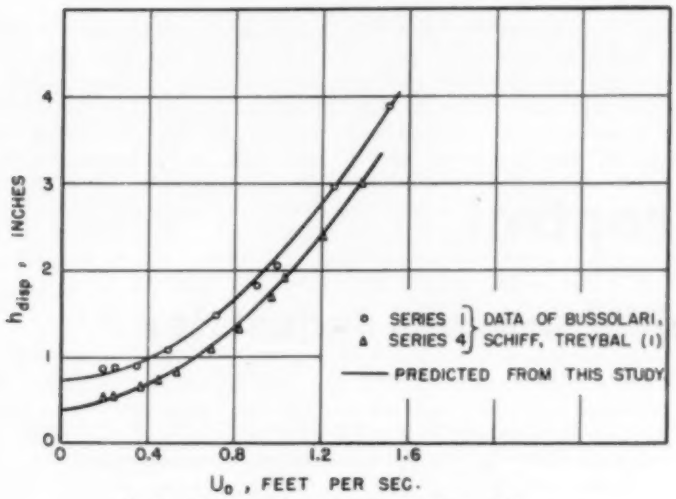

Fig. 7. Experimental and predicted values of h_{disp}.

was about half of that at which flow was initiated and represents the observed value of h'. In certain runs it was not possible to measure h' because the combined thickness of the plate and gasket was greater than h'. A comparison of the observed values of h' with those obtained from plots of h_{disp} vs. U_o^2 is presented in Table 3.

By subtracting h' from h_{disp}, one obtains a corrected depth, h, which represents the depth of dispersed phase required to overcome the orifice effect. Corrected orifice coefficients were calculated by the use of the equation

$$C_o = \frac{U_o}{\sqrt{2g\left(\frac{\Delta\rho}{\rho_D}\right)\frac{h}{12}}} \qquad (4)$$

Figure 5 shows a plot of C_o vs. Reynolds number for all the runs presented in Table 2. It will be seen that, unlike Figure 4, a single curve now satisfactorily represents all the systems. The solid line in Figure 5 represents the equation

$$C_o = 1.00 - \frac{0.71}{\log Re} \qquad (5)$$

By the use of Equations (4) and (5) it is possible to calculate the value of h from the properties of the system. The chart shown in Figure 6 has been designed to simplify the solution of Equations (4) and (5).

Figure 7 shows a comparison of the data actually obtained by Bussolari, Schiff, and Treybal in their Series 1 and 4 and the predicted curves obtained by use of Equations (3), (4), and (5). Comparisons with their other seven runs, not shown in Figure 7, revealed equally good agreement. The present method is superior to that proposed by the foregoing authors in that one curve represents the complete range of orifice velocities of a given plate. It is therefore not necessary to smooth the juncture between two separate curves, as described by those authors.

DOWNSPOUT EFFECTS

Bussolari, Schiff, and Treybal proposed three separate equations for the calculation of the depth of light liquid required to overcome losses due to contraction, expansion, and change in direction of the heavy liquid flowing through the downspout. In view of the fact that in a great many cases their observed values deviated from the calculated ones by 200 or 300%, it appears that a simplification of their equations would not result in any significant sacrifice of accuracy. Accordingly, the present authors recommend that these equations be modified so as to combine these three losses into one simplified equation as follows:

$$h_{CEB} = \frac{0.92U_D^2\rho_C}{\Delta\rho} \qquad (6)$$

This equation was derived by neglecting the velocity of the heavy liquid in the column cross section and combining the three equations proposed by the previously mentioned authors.

Proposed Design Method

On the basis of this investigation it is recommended that the following procedures be used for calculating the total depth of interface and the dispersed-phase velocity:

Case I. DEPTH OF INTERFACE UNKNOWN

1. Calculate h' by Equation (3).
2. Calculate $d_o\rho_D/\mu_D$ and U_o. From Figure 6, read $(\Delta\rho/\rho_D)h$. Multiply this value by $(\rho_D/\Delta\rho)$ to obtain h.
3. Calculate h_{CEB} by Equation (6).
4. Total depth of the interface is equal to $h' + h + h_{CEB}$.

Case II. DISPERSED-PHASE VELOCITY UNKNOWN

1. Calculate h' by Equation (3).
2. Calculate h_{CEB} by Equation (6).
3. Calculate h by the equation $h_t = h' + h + h_{CEB}$.
4. Calculate $(\Delta\rho/\rho_D)h$ and $d_o\rho_D/\mu_D$. From Fig. 6, read U_o.

Notation

C = over-all orifice coefficient, dimensionless
C_o = corrected orifice coefficient, dimensionless
d_o = orifice diameter, in.
D_o = orifice diameter, ft.
g = acceleration due to gravity, 32.2 lb. mass feet/(lb. force)(sec.^{2})
h = depth of layer due to orifice effect, in.
h' = depth of layer obtained by extrapolating h_{disp} to zero orifice velocity, in.
h_{CEB} = combined depth of layer due to contraction, enlargement, and change in direction of continuous liquid, in.
h_{cont} = depth of layer due to flow of continuous liquid, in.
h_{disp} = depth of layer due to flow of dispersed liquid, in.
h_t = total depth of dispersed phase below top surface of plate, in.

Re = Reynolds number for dispersed liquid through orifice $= D_oU_o\rho_D/\mu'_D$ (dimensionless
U_D = average velocity in downspout, ft./sec.
U_o = average velocity through orifice, ft./sec.
μ_C = viscosity of continuous phase, centipoises
μ_D = viscosity of dispersed phase, centipoises
μ'_D = viscosity of dispersed phase, lb./ft. sec.
$\Delta\rho$ = differential density $= \rho_C - \rho_D$, lb./cu.ft.
ρ_C = density of continuous phase, lb./cu.ft.
ρ_D = density of dispersed phase, lb./cu.ft.
σ = interfacial tension, dynes/cm.

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statistical quality control in the chemical process industries

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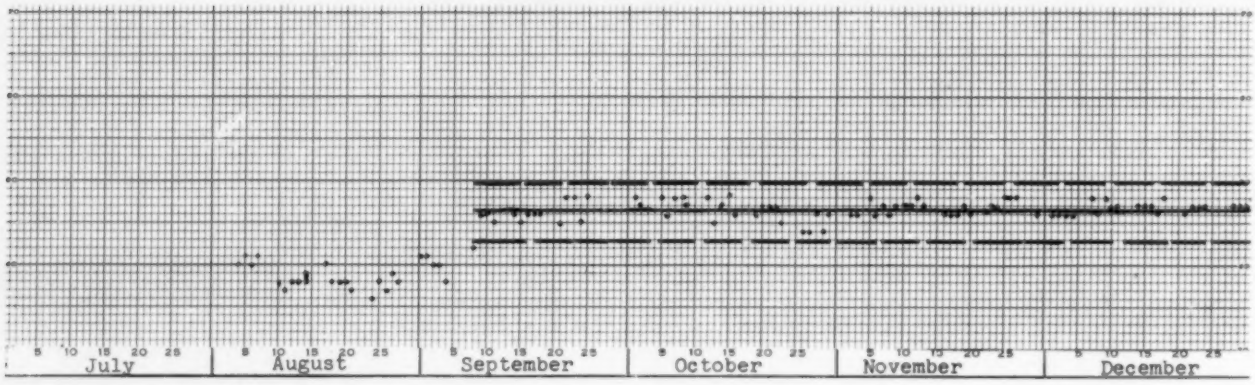

Fig. 1. Analyses of first shipment each day.

Statistical quality control is a rather general mathematical technique used extensively throughout industry. Possibly the distinguishing feature in such technique is the use of probability in evaluating data and in the explicit formulation of the conditions necessary to support an hypothesis. Basically, statistical quality control is a technique which describes the conditions necessary for proving statements concerning data and defines the limits of reliability of the proof in terms of probability units.

The extent of possible application of statistical quality control to the chemical process industry is probably unlimited; however, since statistical quality control techniques have become only recently a part of management tools, the potential economic value of the statistical approach is not yet generally appreciated. This paper presents illustrations of how statistical quality control techniques were applied in the Texas Division of The Dow Chemical Company along with the basic approach involved.

It will be helpful in the understanding of statistical quality control techniques to present some fundamental ideas on the meaning of frequency distributions. Any repetitive process will generate data with a variation pattern characteristic of the process. Our ability to understand what the process is doing is in a sense measured by the information of the pattern of variation, and our ability to control a process is directly affected by our recognition of significant changes in the data pattern.

In the usual processing of materials a naïve point of view might be that the process has been set to operate at a desired average and any deviation from this average is evidence of lack of control. If this point of view were taken seriously—and apparently sometimes it is—the logical consequence would be to seek causes for any deviations which occur. Such attempts more often than not lead to failure.

The statistical quality control approach provides the realization that chance variables are always present in measured data, and that no process is constant in the sense just described. What is defined in using statistical quality control techniques is the probability of occurrence of data within prescribed range limits when no significant process changes have occurred. Once the characteristic data pattern of a process has been determined, use can be made of this pattern to predict the limits within which future data can be expected to fall as a matter of chance variation. Also the process data pattern can be used to determine when significant process changes have taken or are taking place.

The judgment as to whether a significant change has occurred in the data from a process is based on probability considerations, which arise as a result of the treatment of frequency distributions as probability distributions. What

is meant by this will be clear from what follows. If we have a group of data from a process operated under uniform conditions, and if we arrange these data in increasing order of magnitude, we can determine the percentage of the data falling within any prescribed limits. If these limits are $X_2 - X_1$, then the fraction of the data in the range $X_2 - X_1$ is

$$\frac{X_2 - X_1}{N} \qquad (1)$$

where N is the total number of values. By taking equal increments such as $X_3 - X_2$, $X_4 - X_3$, $X_5 - X_4$, etc., the fraction of the data in each range can be determined by a repetition of formula (1) for each range of values. The determined relative frequency for values in the range $X_2 - X_1$ is that shown by formula (1), and the probability of finding values in this range $X_2 - X_1$ is defined as

$$P(X_2 - X_1) = \text{limit} \frac{X_2 - X_1}{N} \Bigg| N \to \infty \qquad (2)$$

In general, we will not be able to determine what the limit of Equation (2) is because there is no certainty that the same operating conditions will apply as more and more data are obtained (*i.e.*, as $N \to \infty$).

However, as a practical solution we can let our experience under a set of uniform operating conditions define $P(X_2 - X_1)$ by using formula (1), or use can be made of $R(X_2 - X_1)$, where R is the relative frequency.

By having the relative frequency (*i.e.*, probability of occurrence) of values in a series of consecutive, equal ranges, one can then predict what to expect under the conditions of uniform operation. As an illustration of the application of this idea of probability distribution (*i.e.*, relative frequency), suppose we have determined that the voltages obtained from electrolytic cells form a statistically normal distribution when measured on a given day. Then the equation

$$F(X) = \int_{-\infty}^{X} \frac{e^{-1/2y^2} dy}{\sqrt{2\pi}},$$

$$0 \leqslant F(X) \leqslant 1 \qquad (3)$$

where $F(X)$, the frequency of occurrence of values up to X, can be used to find the probability of obtaining values within the range $X_2 - X_1$ on future measurements if no significant changes occur in the factors affecting cell voltages. The integration of Equation (3) will usually not be necessary since tables for this integral are available. Suppose we have obtained from this integration the information that we may expect values in the range below a specified voltage value, say, once in a thousand measurements, merely as a chance result of the random combination of the factors affecting cell voltages as measured. If we obtain a value in this .001 probability area, we can decide with a very small risk when the number of data is small that the value obtained was the result of a significant change in the process. If a voltage value falls within a .000001 probability area, the decision that a significant change occurred (intentional or unintentional) is once again subject to a risk of being wrong, but the odds are so great that as a practical matter we would automatically assume that a significant process change had occurred, and we would possibly begin to look for this change.

The discussion above illustrates a fundamental application of the statistical (or probability) approach to the evaluation of a single piece of data with reference to the occurrence of a significant change in a process. Amplification of this probability approach leads to the following important applications.

1. **Determination of significant differences in process averages.** From the distribution of data on individuals the relative frequency of occurrences of averages of any particular sample size can be determined. These averages can be treated then in the same manner as indicated above for individual data. That is, we can determine if a significant shift has occurred in an average in terms of the probability area within which it falls.

2. **Determination of correlations among variables.** Where data on simultaneous measurements are available on two or more variables, we can determine whether there is any evidence of correlation in the variables, and the extent of the correlation. This is done, basically, by determining the probable patterns, as measured by some appropriate statistical function, that can result by a random selection of data from the frequency distributions represented by the various variables. If the probable range of values determined for the correlation function by random selection brackets the values actually determined, then the evidence of correlation is poor. However, if the determined correlation function is one that could be obtained by chance, very infrequently then we say that the variables are correlated.

3. **Determination of significant changes in process variability.** From the probability distribution of individual data we can predict the limits within which we expect the process range to fall as a matter of chance occurrence, and by defining such limits, we can determine when the process range has changed significantly. Fundamentally, the same procedure is involved. We define a process variability (range) function and determine its probability distribution. If a particular variability function falls within a very low probability area, we are confident within appropriate limits that the process variability has changed significantly.

These applications are fundamental and probably cover most of the area of interest in data evaluation in routine process operations. The applications which follow are illustrations of some of the fundamental approach described above.

Problem 1: Improving Product Uniformity

A considerable number of packages of Product A are shipped to customers. Each shipment had to meet rather close specifications for purity; hence each shipment had to be sampled and analyzed. The result was a large analysis bill. The question arose on the possibility of reducing the frequency of analysis. More specifically, interest lay in whether the sampling and analysis of the first shipment per day would give an adequate representation of subsequent shipments made that day.

Examination of the plant data and consideration of the cost factors indicated that

shipping and billing of all shipments on the basis of the analysis of package samples from the first shipment made each day could be effective provided that processing variations in manufacturing Product A were reduced. Fundamentally, the initial problem was one of improving product uniformity and, in this respect, the plant data indicated that the manufacturing process was capable of considerable improvement. Analysis of consecutive data for the properties of interest indicated that potentially the process was capable of manufacturing Product A within a narrow band of values, but that in normal operations the process average was allowed to vary at will within the specification range. This meant that when the process average was close to the specification limits, the extreme values around the process average would tend to fall outside the specifications. When this happened the process average would be adjusted radically with a resulting tendency to push the average to the other extreme of the specification limits.

What was needed was some criteria to enable the plant operators to judge when the process average had strayed far enough to justify making compensating adjustments. This need was provided in the form of a control chart which specified a target value, *i.e.*, the average of the specification limits, and a range within which the product analysis would vary normally without adjustments. The range was chosen from plant data which defined the limits which the process was capable of main-

taining. The control chart defined clearly what was desired and the range that could be maintained. The immediate effect of this definition of capabilities and the use of the control chart was to reduce the product analysis variations by more than 50 percent. An idea of the improvement in terms of meeting specifications is shown in Figure 1.

After Product A analyses were made to conform more closely to the specifications average, the billing of all Product A shipments on the basis of the analysis of samples from the first shipment each day became feasible. In reviewing the possible approaches to an evaluation of the effects of billing on the first daily shipment basis, it was decided that:

a. An evaluation would be made to determine how close the existing sampling and analysis procedure represented the *true* value of the shipment.
b. An evaluation would be made of how well the first shipment samples each day represented subsequent shipments that same day.
c. A comparison of the existing billing basis and the billing on single daily shipment samples would be made and evaluated in terms of costs.

a. Evaluation of the Existing Methods—All Shipments Analyzed

Customer billings were made on the basis of the average of duplicate analyses for each shipment sample. The duplicate analyses provided a convenient source of data for estimating the precision of the analytical method. The practical significance of estimating the analytical precision was that it was a direct measure of the limits within which the true analysis of any shipment sample fell. The frequency distribution of the differences in the duplicate analyses (Table 1) with the use of the first of the duplicates to measure the difference was a statistically normal distribution with a standard deviation of .084%. The billing analyses were based on the average of the duplicates. The standard deviation of the averages would be less than .084 percent, *i.e.*, $.084/\sqrt{2}$ in accordance with a conversion based on the relation

$$\sigma_{x'} = \frac{\sigma_x}{\sqrt{N}}$$

where σ_x is the square root of the mean square of the deviation of the individual differences from the average difference, N is the number of replicates in the analyses (2 in this case), and $\sigma_{x'}$ is the standard deviation of the average of individual differences when duplicate checks are used. The value of $\sigma_{x'}$ is a measure of the dispersion around the true sample analyses resulting from the lack of complete precision in the analytical method.

The distribution of the deviations of the shipment sample analyses from the true analysis is shown in coded form in the tabulation below.

Expected Deviations of Average of Duplicates from True Sample Analysis	Relative Frequency of Occurrence
%	%
—0.1	10
0.0	80
0.1	10

Table 1.—Distribution of Differences between Duplicate Checks on Concentration

Difference in Duplicate (%)	Frequency	Frequency (%) Relative
—0.2	3	2.2
—0.1	15	11.2
0.0	99	73.9
0.1	11	8.2
0.2	6	4.5

b. Evaluation of Analysis of First Shipment Each Day Followed by Billing Subsequent Shipments on Basis of First-Shipment Analysis.

Distribution of the analytical differences between first and subsequent shipments made each day is shown in Table 2 in coded form consistent with the units of Table 1. The distribution values of Table 2 were obtained from data after the use of control charts and reduction in product variation, in order that a comparison of the existing sampling and analytical method and the first daily shipment analysis could be made directly. This is done in Table 3 in terms of billing differences.

Table 2.—Distribution of Differences between the First and Subsequent Shipment Package Samples Analyzed Each Day

Difference (%)	Relative Frequency (%)
—0.3	0.44
—0.2	5.1
—0.1	24.5
0.0	40.0
0.1	24.5
0.2	5.1
0.3	0.44

c. Comparison of Billing Basis in Terms of Costs

Table 3 is in a sense a comparison of deviations under two methods of operation. The existing practice indicated that 20 percent of the time the customer would be billed within .025 percent of the true shipment cost, either plus or minus with equal frequencies. These differences from the

Table 4.—Shipment Analyses from Terminal Shore Tank

(Coded Data)

Shipment No.	% Concentration	A % Impurity	B % Impurity	C P.P.M. Impurity
1	99.6	.044	.344	6
2	99.6	.046	.344	6
3	99.6	.046	.344	5
4	99.5	.048	.344	5
5	99.6	.048	.344	5
6	99.5	.046	.340	5
7	99.5	.046	.342	5
8	99.6	.052	.342	6
9	99.6	.046	.344	5
10	99.6	.048	.342	5
11	99.7	.046	.344	5
12	99.6	.048	.344	6
13	99.6	.046	.344	8
14	99.6	.046	.340	6
15	99.6	.048	.342	7
16	99.5	.046	.342	6
17	99.6	.046	.342	6
18	99.6	.048	.344	5
19	99.6	.046	.342	5
20	99.6	.048	.344	5
21	99.6	.048	.344	5
22	99.7	.044	.344	5
23	99.6	.046	.342	5
24	99.6	.046	.344	5
25	99.7	.046	.344	5
26	99.7	.048	.344	6
27	99.7	.048	.344	8
28	99.7	.048	.342	8
29	99.6	.048	.346	5
30	99.6	.048	.344	5
31	99.6	.046	.344	5
32	99.6	.046	.344	5
33	99.6	.044	.346	6
34	99.7	.046	.348	5
35	99.6	.044	.344	5
36	99.6	.046	.346	8
37	99.6	.044	.342	5
38	99.6	.048	.346	5
39	99.7	.046	.346	5

Table 3.—Comparison of Analysis of Package Samples from All Shipments and Analysis of First Shipment Samples Each Day

Billing Difference in % of "True" Cost of Shipments—Coded Data	Relative Frequency of Occurrence	
	All Shipments Analyzed (%)	First Shipment Analyzed Each Day (%)
—.075	..	0.44
—.050	..	5.1
—.025	10	24.5
.000	80	40.0
.025	10	24.5
.050	..	5.1
.075	..	0.44

true value of the shipments are quite small, and, since they average out, represent no net loss or gain to the customers or the company. In terms of the distribution of billing differences when only the first shipment each day is analyzed, the individual variations from zero occur more often and the range of differences is somewhat larger for some 11 percent of the shipments.

The present practice at Dow is to bill Product A on the basis of the analysis of the first shipment each day. This practice has been satisfactory both to the customers and to the company. The result is that more uniform product is now shipped than formerly, and that approximately three analysts are able to devote their talents to more useful projects.

Problem 2: Improving Sampling Procedure

Marine shipments are made to terminals from which subsequent shipments are made to customers. Each shipment from the terminal was billed according to the analysis of a sample from the terminal loading. A reduction in the frequency of sampling and analyzing was desired.

After receipt of each marine shipment, the terminal tank inventories were regarded as essentially constant throughout any one tank. However, because of the layering of one ship load on another, some possibility of nonhomogeneity existed; hence it was desirable to make this variation small in order to assume that uniformity within a tank was reasonable. This was done by improving the uniformity of the product along lines similar to that discussed in Problem 1.

Analysis of the data of the shipments made from the terminal (see Table 4) indicated the type of variation expected when no additions were made to the terminal tanks. From these data the assumption of uniformity of product within a tank between loadings into the tank seemed quite justifiable. Also, the billing of all shipments from the terminal on the basis of a precise representation of the tank's contents seemed plausible.

The billings of the shipments from the terminal were based on the concentration data of Table 4 (second column) so that these were used to estimate the required number of tank samples. From the standard deviation of the concentration data an adequate scheme was developed with the use of six samples selected at random throughout a tank. The billings were to be based on the average of the six samples. However, in order to show the validity of the use of a six-sample average, a paper experiment was made as follows:

The analyses of Table 4 were listed in their chronological order and numbered 1-39; random selections of six individual samples were made so that ten groups of six samples each were obtained. The averages of all of the ten groups of six were then compared to the average of all of the shipments made from the terminal tank, i.e., of the concentration data of column 2 of Table 4. All these averages of 6 were shown to be within .045 percent of the average of all the thirty-nine shipments. Since the billings were made to the nearest 0.1 percent, averages of the six randomly selected samples represented the tank contents within less than 0.1 percent, so that the analytical deviations involved in billing of terminal shipments were smaller with the six-sample average than with the one sample per shipment billings.

The present practice in terminal shipments of this product is to bill all shipments on the basis of the average of six random samples from a terminal tank after receipt of a marine shipment. The result of this practice is that 80 percent of meaningless analyses have been eliminated and the customers are billed more accurately.

Problem 3: Elimination of Unnecessary Analyses

In the production of Product B, analyses of samples were made from each of the reactors manufacturing Product B with a relatively high frequency. These samples were taken in order to learn whether off-specification material was being produced,

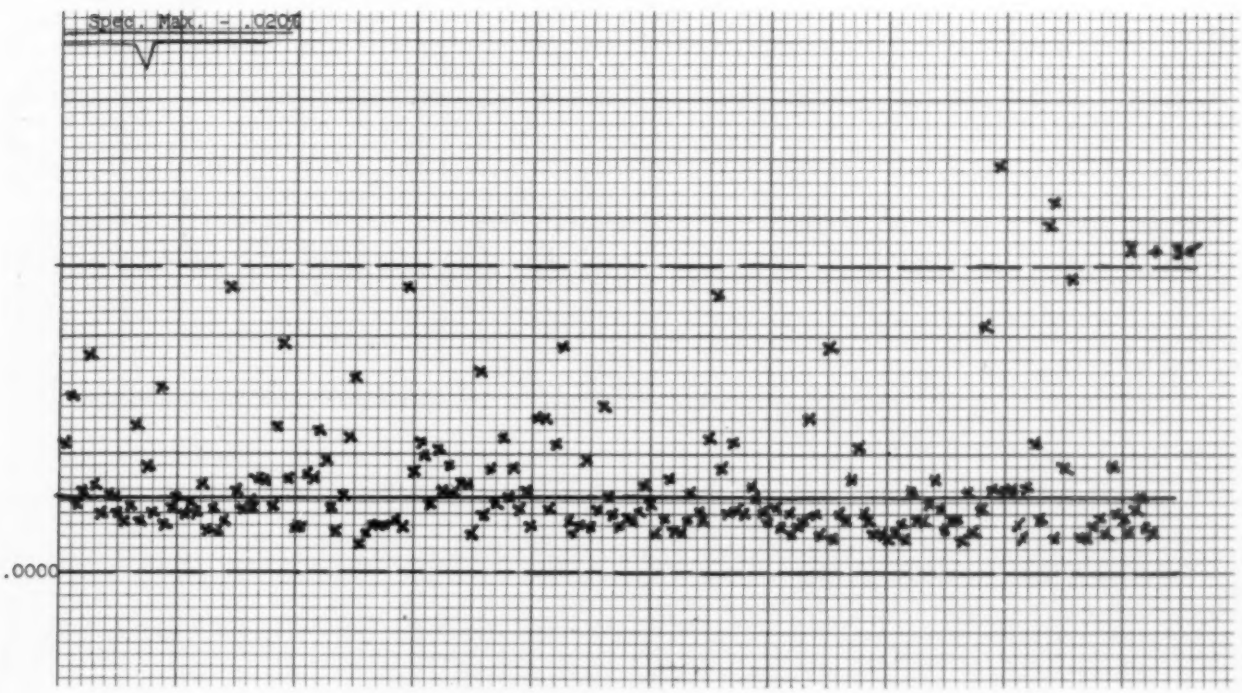

Fig. 2. Per cent impurity A, January-September, 1953 (August not included).

and to determine the actual range of properties being manufactured. The shipment or use of off-specification material could affect the end use properties adversely, so that it was thought necessary to analyze quite often.

The presentation of the impurity data in terms of control charts showed that even with the variations resulting from usual changes in processing, little likelihood existed of exceeding the specifications for any of the impurities (see Figures 2, 3, and 4). This meant that the existence of off-specification material resulted from unusual circumstances rather than from peculiar combination of process variables, and therefore would be as likely to occur anywhere. The finding of these off-specification batches of material would mean sampling and analyzing to an extent which would be utterly impractical. Also, as the frequency of occurrence of these off-specification batches was quite small, none having been observed in 9 months of data, the problem would be one like finding a needle in a haystack.

With the information of the control charts of Figures 2, 3, and 4, the basic approach in impurity analysis was changed to that of obtaining information on the general range of properties being produced and the frequency of sampling reduced to give a reliable estimate of this. The frequency of sampling and analyzing was reduced to approximately one sixth its former value.

Presented at Ninth annual one-day South Texas Meeting, October 22, 1954.

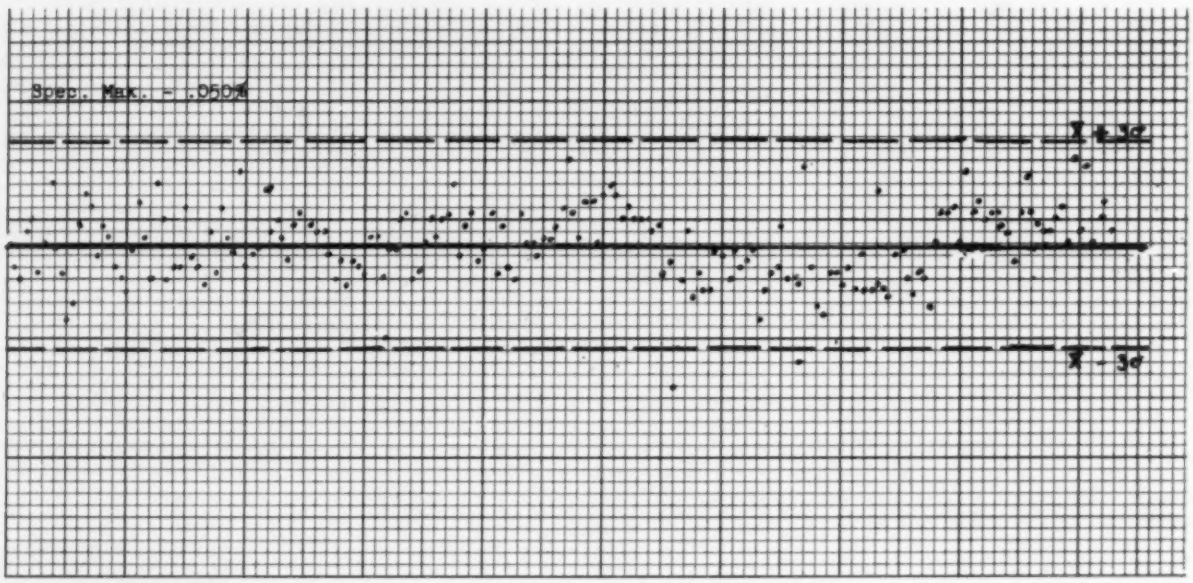

Fig. 3. Per cent impurity B, January-September, 1953 (August not included).

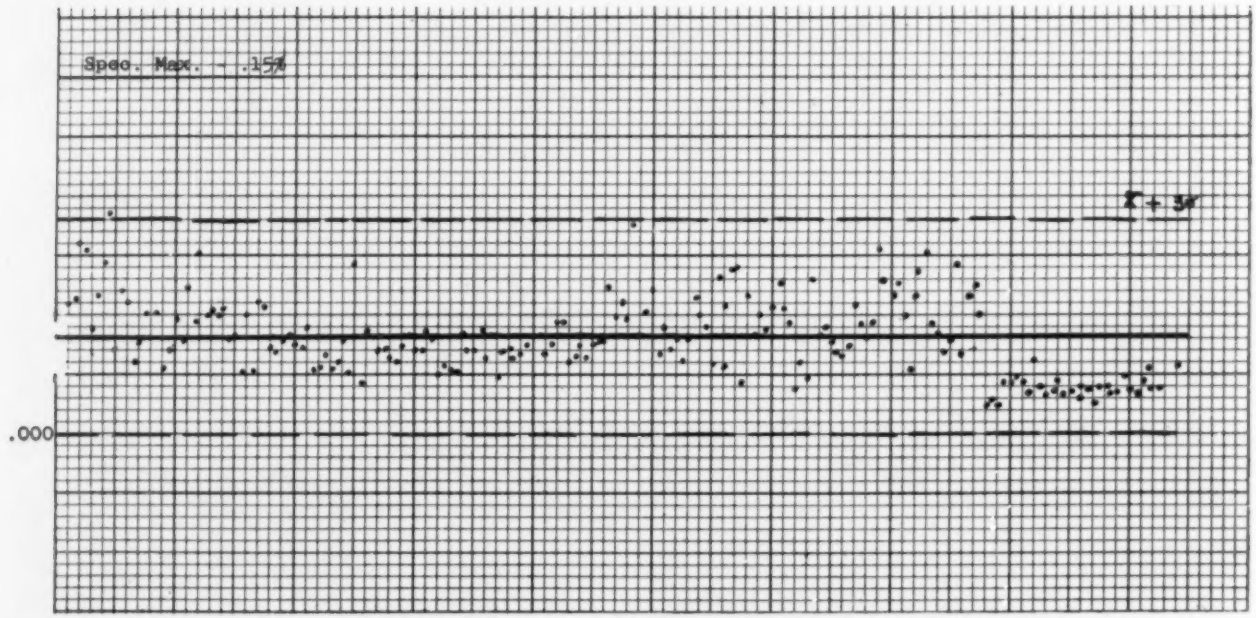

Fig. 4. Per cent impurity C, January-September, 1953 (August not included).

Mixer with top removed (after use with glass beads in mixture, run 1a).

a fundamental study of the mixing of particulate solids

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The random nature of the operation of mixing particulate solids is described, and quantitative definitions of mixing, theoretical random equilibrium mixture, and degree of mixing are developed from a model of the operation of dry mixing which takes into account sampling procedure. These ideas are analyzed theoretically and illustrated with experimental data. The model is applied to the evaluation of mixing-system performance by a standard chi-square test and a new evaluation system based on chi-square. *Degree of mixing* is defined as the ratio of a theoretically calculated standard deviation for a random equilibrium mixture to the experimentally determined standard deviation among spot samples. A rate equation is proposed and is tested by mixing −40/+50 (U.S.) mesh sand and salt in a rotating horizontal cylinder. The equation holds for the initial mixing period. On longer mixing the central portion of the mixer develops a higher sand concentration than do the ends, a condition attributed to tumbling differences between the two kinds of particles and tumbling surface curvature near the ends. Different sampling methods are investigated, and the importance of complete reporting of sampling procedure is emphasized.

Dry mixing, or dry blending, is a widely used operation in the chemical industry, some of its applications being in the manufacture of food, drugs, glass, soap powders, metal powders, paint pigments, and cosmetics. However little fundamental study on the mixing of particulate solids is generally available, and previous literature does not always provide methods and data. Hence definitions of terms such as *degree of mixing* differ. It is difficult to evaluate theories and compare results on a common basis.

This study was intended to obtain basic information on an elementary dry-mixing operation, to check previously recommended procedures, to develop and test new ones, and to devise a method for following or predicting the course of a mixing operation. The aim is to analyze rate and extent of mixing, with an eye toward correcting the physical phenomena which hinder good blending.

This article is based on a Ph.D. dissertation by Sherman S. Weidenbaum, Department of Chemical Engineering, Columbia University, New York, New York, June, 1953. A microfilm copy of the complete 234-page manuscript (publication 6733) may be obtained for $2.93 from University Microfilms, 313 N. First Street, Ann Arbor, Michigan.

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proximately the batch level (Figure 3b). Suction, ranged from a nonmixed state to approximately

Table 1

	Ottawa sand	Salt
Shape	Smooth but irregular	Cubic crystals
Size (see text)	−40/+50	−40/+50
Density (Handbook values of SiO_2 and NaCl)	2.20	2.16
Bulk density (g./cc.)	1.54	1.16
No. of particles/g.*	16,100 s.d.† = 400	19,300 s.d.† = 200
Angle of repose	30.5°, s.d. = 1	Dried 34° s.d. = 1 Undried 37° s.d. = 1.5

* See (13) for method of determination.
† Standard deviation.

The experimental work was performed in a horizontal right-angle cylinder rotating about its axis, initially loaded on one side with salt and on the other with sand of the same size. The method chosen for defining the degree of mixing is based on the standard deviation of the compositions of a number of spot samples of a specific size taken at fixed, uniformly distributed locations throughout the batch. The ratio of the theoretical standard deviation for a completely random mixture to the actual experimental standard deviation of these compositions is designated the *degree of mixing*. A model for the mixing operation is given in terms of the change in frequency distribution of the compositions of the spot samples as mixing progresses.

Literature

Various approaches to the study of mixing problems have been used in the past. To derive a rate equation Brothman, Wollan, and Feldman (*3*) and Coulson and Maitra (*6*) employ the rate of enlargement of the "surface of separation" between the materials being mixed. The two papers differ in the method of converting the expression involving the surface of separation, each leading to a different rate equation. Only Coulson and Maitra (*6*) carried out experimental work, and this concerned several binary systems in a simple drum mixer at various angles with the horizontal. Beaudry (*1*), Lacey (*8*), and Buslik (*5*) have dealt with statistical ideas, the first discussing blender efficiency and the other two making a start toward fundamental development of the meaning of *mixing* and *degree of mixing*. Visman and Van Krevelen (*12*) recently reworked data of Maitra and Coulson (*9*) to test another method of plotting rate data. Methods earlier considered by the second author for defining degree of mixing utilized the deviation of spot sample compositions from their mean, with correction for different sample sizes and batch compositions. For ease of computation the mean deviation was employed rather than the standard deviation (*2*). Plots of $\log (a.d./2c(1-c)) - \log ((a.d.)_{perfect}/2c(1-c)) = \log a.d./(a.d.)_{perfect}$ vs. $\log r$ (*see* Table 4 for definitions), which roughly approaches an arctan curve, were indicated. The efficiency of a mixer could be computed from the slope of the best straight line on arctan paper. Oyama (*10*) has made an extensive study of many aspects of the mixing of granular materials. A few of the varied topics he covered are particle motion, the effect of a lifting flight, power consumption, and packing. Brown (*4*) discussed the shape of vessels currently used in the batch mixing of powders. Young and Snaddon (*14*) described an adjustable angle mixer for small laboratory samples of solids such as are used in chemical analysis. Redd (*11*) described the cascading and flow patterns of a conical blender and gave general ideas on batch capacities, applications, and approximate mixing times necessary to achieve a "good blend" in this type of machine. A detailed analysis of these articles is available elsewhere (*13*).

Review of the literature points up the need for comparing and coordinating previous studies. In particular, articles on the statistical aspects give little attention to the kinetics approach, and those emphasizing the latter often do not give adequate attention to statistical methods.

Materials, Equipment, and Procedure

The mixing equipment was a transparent horizontal right-angle cylinder made of Lucite and Plexiglas which rotated at approximately 45 rev./min. in a ball-mill machine with a special holder. The materials mixed were Ottawa sand and cubic salt crystals of which 93-96 wt. % was −40/+50 (U.S.) mesh, the rest −30/+40 and −50/+70. Table 1 gives some important physical properties of the salt and sand.

Approximately 600 cc. of each material was used, the total batch volume comprising about one third of the inside cylinder volume. Mixer construction details are shown in Figure 1. The cylinder was chosen because it was simple and inexpensive. Its use does not imply that this type of equipment is best for mixing. In the section on Axial Concentration Gradient a shortcoming of this apparatus is discussed.

Sand and salt, loaded on opposite sides of the mixer, were separated by a removable partition until the run began. Starting in this position, the cylinder was revolved the desired number of revolutions, stopped, and sampled. The type of tumbling motion is illustrated in Figure 2.

The principal sampling method employed twenty-seven spot samples, most of which had 120 to 160 particles. They were taken by a sampling thief of the type used by Maitra and Coulson (see Figure 3a), inserted at three horizontal levels corresponding to the bottom three plugs of Figure 1. Particle counts of each component were made on each spot sample, a linen counter being used for magnification. Putting one sheet of Polaroid under the slide on which the particles were placed and another under the lens made clearer identification possible because of the difference in appearance of the two kinds of particles under polarized light.

The large samples of run 2a were taken by means of a thin-walled metal tube having a piece of 150-mesh wire cloth across the inside at ap-

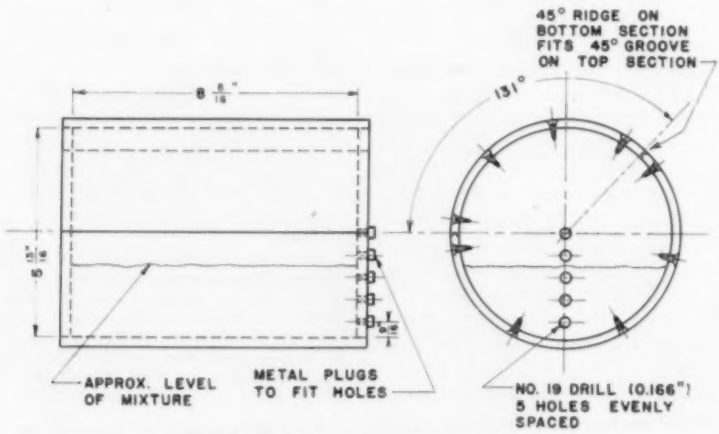

Fig. 1. Cylindrical mixer used in experiments.

Fig. 2. End view of mixer in motion.

proximately the batch level (Figure 3b). Suction, applied at the top end of the tube, inserted vertically into the batch through a spacer template, enabled the removal of a "slug" of mixture, which was released into a weighing basket when the suction was broken. The weight fraction of each component was determined by dissolving out the salt. Nine such samples of approximately 0.83 g. each were taken at equal intervals along the lengthwise axis of the cylinder.

Experimental Work

Three extensive runs were carried out. Run 1 took place in hot and humid summer weather and run 2 during the autumn. In both 1 and 2 the cover of the mixer had to be removed at times during the course of the run. Run 3 was performed in dry winter weather and the mixer was kept sealed except for one brief cover removal at 18,117 rev. In all three runs the materials had been dried in an oven before being inserted into the mixer. All three runs ranged from a nonmixed state to approximately 24,000 rev. A run extended over many days since only a few points could be done each day. The mixture was left undisturbed between points. Run 1 was continued as run 1a for an additional period after glass beads were added to the mixture. Run 2a was that part of 2 which employed the nine larger samples and run 2b that which consisted of the twenty-seven small samples for each state of mixedness. The two sampling methods were compared for twelve different states of mixedness. In each case the nine larger samples were taken first and then the twenty-seven smaller ones. In run 3 a duplicate set of spot samples was obtained 2 or 3 rev. after each set of regular spot samples. Approximately 7 g. of material/run was removed via the small samples in runs 1 and 3. Other special samplings not reported here removed about 30 more grams after run 1 (just before 1a began). Also in run 3 a special sampling at 18,117 rev. removed an additional 7½ g. Run 2, which had only about 4 g. removed via small samples (2b), had 90 more grams removed via large samples (2a). Total weight of salt and sand per run was about 1,625 to 1,645 g.

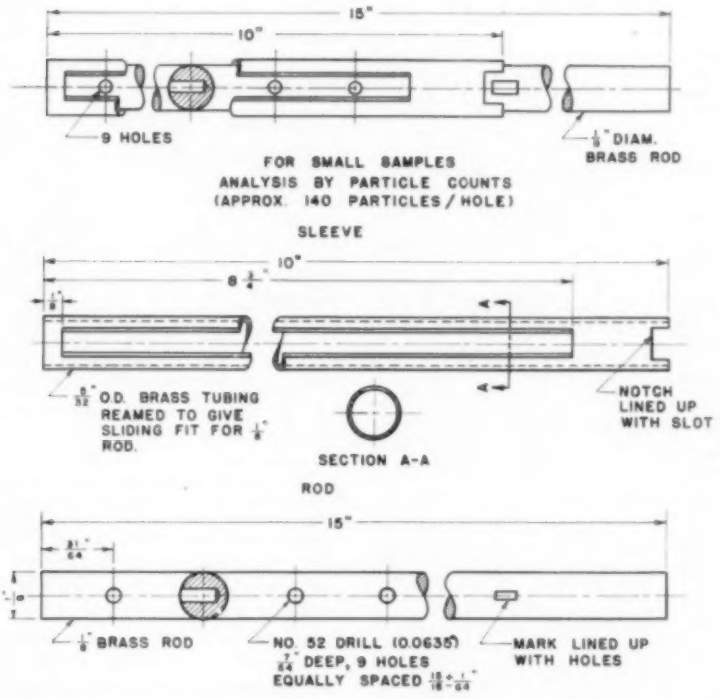

Fig. 3a. Sampling device for small samples. Upper diagram is assembly drawing; lower two are detail.

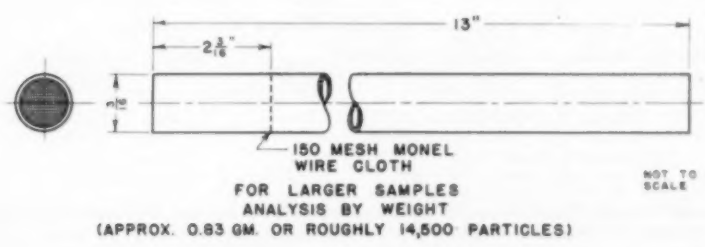

Fig. 3b. Sampling device for larger samples.

Model for Mixing Operation

The model offered here depicts the mixing operation in terms of the change in relative frequency of occurrence of spot-sample compositions in various composition ranges. Initially the salt and sand are loaded on opposite sides of the mixer. Theoretically, samples from this system would be either all salt or all sand except for the contiguous portion. As mixing proceeds, a number of different particle arrangements will occur. Spot samples from these partially mixed states will not be entirely salt or sand but will vary in composition. If there were no conditions causing segregation, after infinite mixing time an equilibrium condition corresponding to some randomly dispersed arrangement of the particles would be reached. For such a system the spot-sample compositions would not be identical. Instead, they would be distributed in a manner dependent upon the mixture composition and spot-sample size. Their distribution curve can be calculated theoretically and approached experimentally by taking sufficient samples from a randomly mixed batch.

A pictorial illustration of this model with data from run 1 is given in Figure 4.

The theoretical distributions for the nonmixed and randomly mixed condition are given in Figures 5 and 6 respectively. Mathematical details and assumptions are available (*13*).

With this model in mind, the following definition is given for the operation of random mixing of particulate solids:

Random mixing of particles of A and B is that operation in which the motion imparted to these particles causes them to assume arrangements such that, as mixing proceeds, the frequency distribution of sample compositions becomes less and less spread out and approaches an equilibrium distribution called the *binomial distribution*, provided that only a small amount of the mixture is used for sampling. (NOTE:—If there are special separating tendencies, then the mixing is no longer purely random.)

Evaluation of Mixer Performance

To determine quantitatively whether a random mixture can be achieved with a given mixing system, statistical methods can be used to compare, via the chi-square test, the distribution of spot-sample compositions obtained experi-

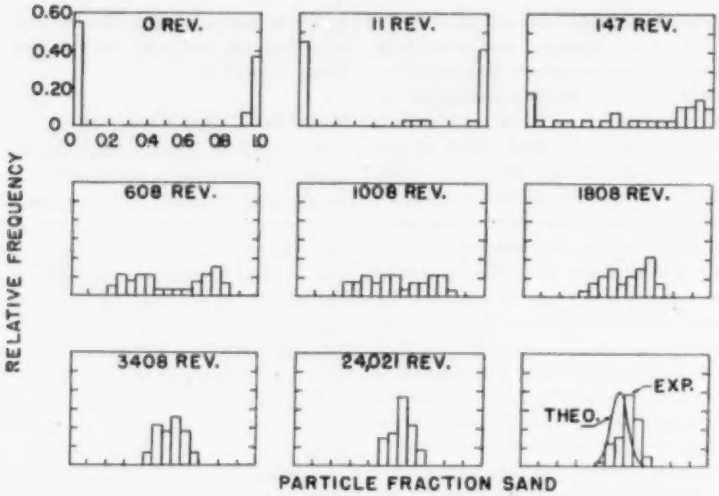

Fig. 4. Illustration of proposed model for following mixing operation with the use of data of run 1. (See Fig. 6 for detailed theoretical curve. Experimental curve based on pooled data of 14,798; 18,113; and 24,021 revolutions.)

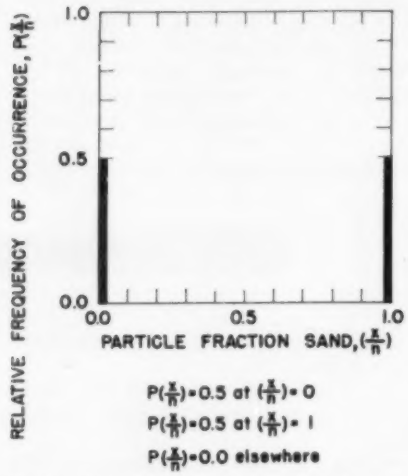

Fig. 5. Theoretical distribution of sample composition for nonmixed batch. This assumes equal numbers of samples in each half of mixer and neglects contiguous portion.

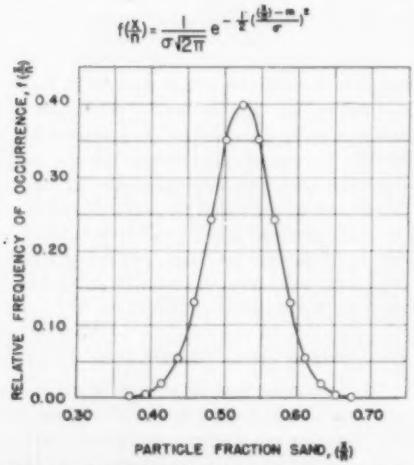

Fig. 6. Theoretical distribution of sample compositions for randomly mixed batch, run 1. (See 13 for further details.)

mentally with the theoretical frequency distribution for a randomly mixed batch. Chi square is defined as

$$\chi^2 = \sum_{i=1}^{k} \frac{(o_i - e_i)^2}{e_i} \qquad (1)$$

where k = the number of pairs of experimental and theoretical frequencies to be compared and o_i and e_i denote these frequencies respectively.

Details of this test are given in the Appendix. The general philosophy will be given here. Two approaches to the use of the chi-square test will be used. The first and more common approach is as a test of significance to answer the question of whether the experimental distribution of spot-sample compositions is significantly different from the theoretical frequency distribution for a randomly mixed batch. The second involves a new way of thinking of the chi-square test, which is to enable investigators to express results on a common basis. Chi-square tables (7) permit the determination of the relative frequency with which any value of chi square based on a specified number of degrees of freedom would occur by chance. Assigning frequency ranges to correspond to common descriptive terms for mixtures such as "good" or "poor" lays the groundwork for expressing results on a common basis. By computing a chi-square ratio for any specific mixture, an investigator can determine from chi-square tables and Table 2 the range into which his mixture would fall. This would improve on the oft-encountered arbitrary designation of a mixture as "good" or "bad," which may depend on whether the buyer or seller is describing it, as well as on the particular use for the product. Usability does not always require a random mixture, which is what is being tested for here via chi square.

Details of this system of evaluation will need further development as situations different from the one given here arise; for example, analysis by particle counts, which was used here primarily, may not always be desirable; perhaps analyses by weight will be necessary. However, the basic approach will be the same, namely to attempt to determine the theoretical distribution of the sample compositions for the specific method of sampling from a random mixture and then, via the chi-square test and Table 2, to classify the mixture.

DEGREE OF MIXING

The value of chi square could be used to describe any partially mixed batch as well as the best attainable mixture for a system.† However, a simpler statistic, which measures the spread of the distribution, is the standard deviation, s (more useful statistically than the average deviation):

$$s = \sqrt{\frac{\sum_{i=1}^{N}\left[\left(\frac{x}{n}\right)_i - \left(\frac{\bar{x}}{n}\right)\right]^2}{N}} \qquad (2)$$

* This way of calculating standard deviation is in common use. According to statistical terminology, it is the biased estimate of the population standard deviation. The unbiased estimate is

$$\hat{s} = \sqrt{\frac{\sum_{i=1}^{N}\left[\left(\frac{x}{n}\right)_i - \left(\frac{\bar{x}}{n}\right)\right]^2}{N-1}}$$

† Although not gone into here, the manner in which both chi-square and standard deviation change with mixing (e.g., a plot of chi-square vs. s) would be interesting.

Table 2.—Proposed General Mixture Classifications *

If relative frequency of occurrence of chi-square value for proper number of degrees of freedom is:	Proposed designation for quality of the mixture
less than 0.10	Very poor
between 0.10 and 0.30	Poor
between 0.30 and 0.70	Fair
between 0.70 and 0.90	Good
greater than 0.90	Excellent

* As with all statistical decisions, 100 per cent certainty is not possible when such a classification is used. However, this method is useful in that it avoids designations of the mixture based entirely on the judgment of the observer, and the types of error are amenable to statistical treatment.

where

$\left(\frac{x}{n}\right)_i$ = particle fraction sand in the *ith* spot sample

$\left(\frac{\bar{x}}{n}\right)$ = arithmetical mean particle fraction sand for the N spot samples.

The theoretical standard deviation for a random equilibrium mixture, σ, is equal to $\sqrt{\frac{p(1-p)}{n}}$

If, instead of standard deviation alone, the ratio of theoretical to experimental standard deviation, σ/s, is used as degree of mixing (as will be the case here), this has the desirable property of approaching unity as random equilibrium is approached. Its value for other states can conveniently be thought of as the fractional distance toward equilibrium. A similar expression was given by Lacey (*8*) although he differs in his approach in obtaining it and in its further development.

The varied types of mixing studies preclude a simple all-encompassing degree of mixing. The unit size of the end product will affect the practical sample size. Also, one can conceive of situations where a little too much of one component would be undesirable, even if the variation between samples was not very high. Furthermore, if a coating of one solid with another is attempted, the theoretical end result is not a random mixture. Although statistical methods can do much as a common denominator for the comparison of mixtures, care must be taken not to use arbitrarily inflexible rules as to number or size of samples arrived at from statistical considerations without equal attention to considerations of the physical situation. Composition gradients due to segregating tendencies, the use to which the mixture is to be put, and the aim of the experimental investigation all play a part in determining methods of sampling. A handy rule is to ask whether the sampling is arbitrary or truly suitable to the problem to be studied and whether the most efficient use is being made of the information in the sample compositions. When any degree of mixing is used, complete details of sampling procedure should be reported, including size, number and location of samples, method of their removal, fraction of mixer contents removed, and method of expressing compositions.

Discussion of Results

RATE OF MIXING CURVES

Standard deviation vs. number of revolutions is plotted in Figure 7 for runs 1, *2b*, and 3. The shape of the curves suggests an initial large driving force causing mixing which is later opposed by an "unmixing" effect. The former is attributed to random motion, this being a powerful driving force initially because the orderly loading arrangement is far from the random equilibrium condition. The "unmixing," shown by the subsequent rise in standard deviation, is ascribed to differences in tumbling properties between salt and sand and to tumbling surface curvature near the end faces. The latter was observed with the cylinder in motion. The net effect is different horizontal components of motion for salt and sand with the type of particle having the larger horizontal component eventually giving a higher concentration in the center. A more quantitative explanation for this system can be offered using the angles of repose given in Table 1 as an indication of tumbling properties. Although the values vary with moisture content, salt is seen to have a higher angle of repose than sand. Accordingly, it can be shown that its horizontal component will be less than that of sand which, according to the previous discussion, would result in a higher sand concentration near the center. This is what was found.

The erratic behavior after the initial sharp drop in standard deviation is not clearly understood.* The ups and downs of standard deviation, however, tie in closely with changes in sand concentration in the sections near the ends as shown for run 3 in Figure 8. For example, the increase in sand concentration for section 1 (Figure 8) parallels the decrease in standard deviation (Figure 7), both curves beginning the irregular behavior at the same number of revolutions.

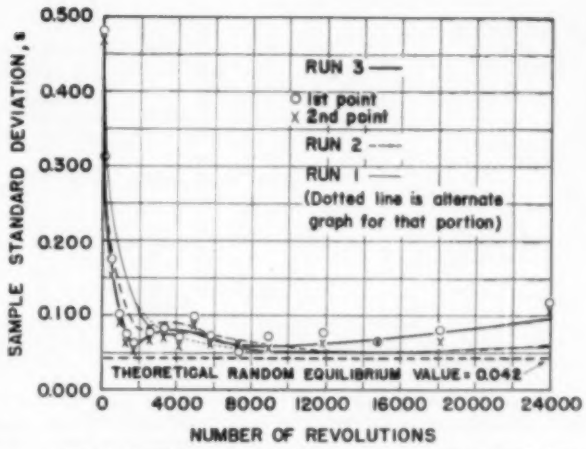

Fig. 7. Sample standard deviation, s, vs. number of revolutions for runs 1, 2b, and 3. Only points for run 3 are shown in order to avoid confusion due to the large number of points. Fig. 13 shows points for run 2b. Data for run 1 are available elsewhere (13). Differences between runs were attributed to differing moisture content of batch due to unequal times of exposure to varying atmospheric conditions.

AXIAL CONCENTRATION GRADIENT

Figure 9 illustrates the axial sand concentration gradient after long mixing periods for runs 1, *2b*, and 3. It was obtained by dividing the cylinder into hypothetical axial sections, the midplanes of which include the sampling spots at the three different levels. The mean fraction sand plotted for each section is the average of the values at the three different levels.†

A qualitative illustration of axial segregation was obtained by adding 5 mm.-diam. glass beads at the end of run 1 and then mixing for a long time (run 1*a*). The beads concentrated heavily at the ends (Figure 10), a result that might have been expected as the (larger) spheres can not start to move until after the small particles have started.

*** In all cases the last two long periods of mixing (approximately 14,000 to 18,000 and 18,000 to 24,000 rev.) gave a rise in standard deviation. Perhaps the slight increase in speed of the motor during this long mixing period caused an equilibrium state with a higher standard deviation than that for the previous shorter periods of time during which the motor did not speed up as much. This is, of course, speculation since there are not enough data to prove this.**

† A statistical approach to studying the axial segregating effect is discussed in Appendix II.

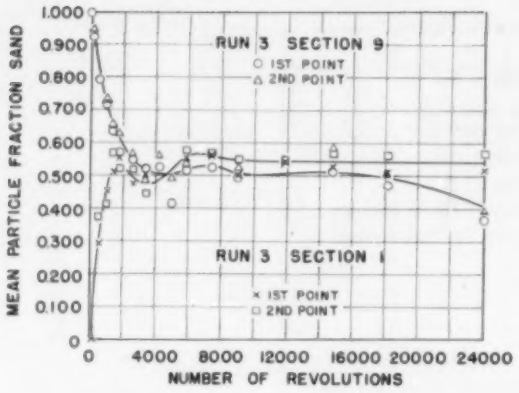

Fig. 8. Change in sand concentration with mixing near the two end sections. (See Fig. 9 for location of sections.)

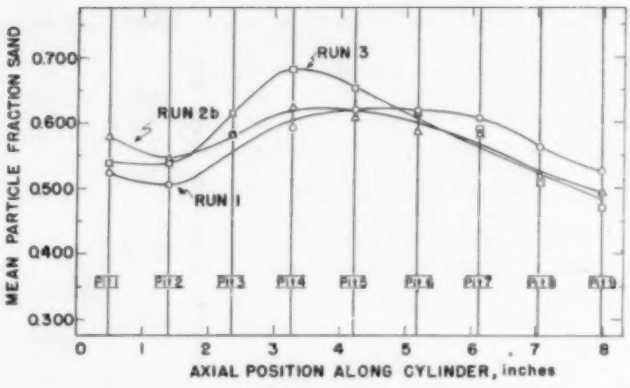

Fig. 9. Axial sand concentration gradient after a long mixing time. The pits lie in the midplanes of their respective sections. Curves for each run are drawn from pooled data of the last three points (approximately 14,800; 18,100; and 24,000 rev.).

ENTROPY

As mixing proceeds, the entropy of the system can be thought of as increasing since it is going from an orderly state to a more probable disorderly one. A quantitative expression of change in entropy in going from state 1 to state 2, ΔS_{1-2}, which is a natural development of the idea behind Table 2, is

$$\Delta S_{1-2} = k'' \ln \frac{P_2}{P_1} \qquad (3)$$

where

k'' = a constant and

P_1, P_2 = probabilities (or relative frequencies of occurrence) of chi-square values for states 1 and 2 respectively

RATE EQUATIONS

It seemed reasonable to analyze the data by a first-order mechanism. Since σ/s can conveniently be thought of as the fractional distance toward equilibrium, the equation for this case would be

$$\frac{d\left(\frac{\sigma}{s}\right)}{dr} = k'\left(1 - \frac{\sigma}{s}\right) \qquad (4)$$

On integrating, this becomes:

$$\ln\left[\frac{1}{1-\left(\frac{\sigma}{s}\right)}\right] = \ln\left[\frac{1}{1-\left(\frac{\sigma}{s}\right)}\right]_o + k'r \qquad (5)$$

The value of the ordinate intercept for this straight-line equation depends on the method of loading. This mechanism was tested by plotting log $[1/1-\sigma/s]$ vs. r for runs 1, 2*b*, and 3, and the resultant graphs are shown in Figure 11. The shape is seen to be a straight line initially, after which the graphs tend to behave irregularly. This suggests that random mixing is initially taking place, as the equation based on the driving force proportional to the distance from random equilibrium applies. The later irregularities in the curves, however, indicate that some driving force which is causing unmixing is becoming more important. This is believed to take place when large quantities of both kinds of materials reach the end faces, and the result is the previously mentioned axial segregation. With this new driving force, which opposes mixing, the rate mechanism based on a driving force due to random motion does not hold.

The shape of the rate graph is probably related to the method of loading. Only an orderly separated loading arrangement was used here. The rate graphs (Figures 7 and 11) might not be similar if the method of loading were changed.

Use of several methods to compute degree of mixing in the integrated form of the first-order rate equation

$$\frac{dA}{dr} = K(A_e - A) \qquad (6)$$

showed that this one equation can yield different rate plots with the same data, depending on the method used for defining A and A_e (Table 3).

Table 4 summarizes different proposed rate equations and methods of plotting data. Those of Bonilla, Crownover, and Goldsmith (*2*) and Visman and Van Krevelen (*12*) were tried with some of the present authors' data with the following modifications in method of plotting: 1) Bonilla, Crownover, and Goldsmith—compositions expressed as particle-fraction sand instead of weight-fraction sand; 2) Visman and Van Krevelen—degree of mixing defined as σ/s rather than as fraction of samples

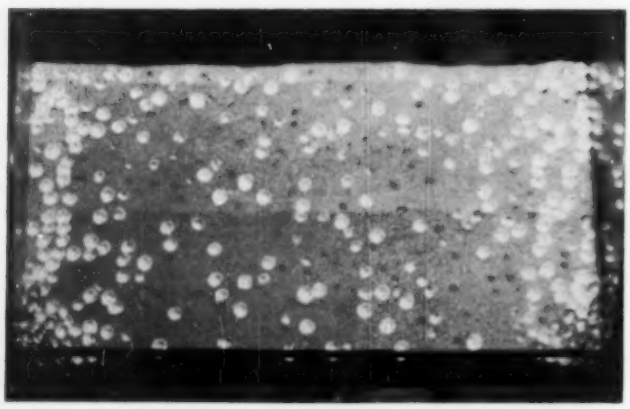

Fig. 10. Position of glass spheres in mixer after stopping machine. Run 1*a*, 52,264 rev. Mixer had been running continuously for 2,948 rev.

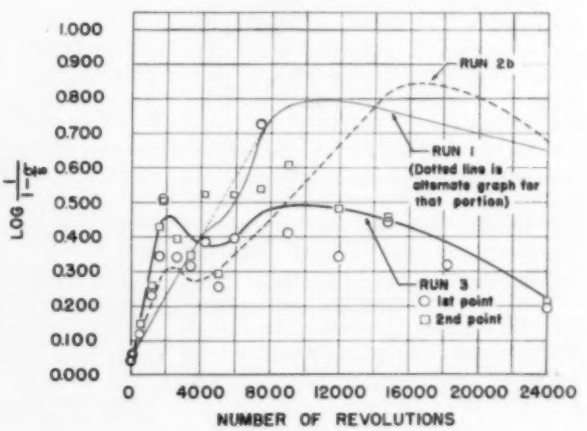

Fig. 11. Log $\frac{1}{1-\frac{\sigma}{s}}$ vs. number of revolutions for runs 1, 2*b*, and 3. Only points for run 3 are shown in order to avoid confusion due to the large number of points. Fig. 14 shows points for run 2*b*. Data for run 1 are available elsewhere (*13*).

Table 3.—Comparison of Various Definitions of A in the First-order Rate Equation $dA/dr = K(A_p - A)$

r = no. of rev. of mixer, K = a constant, A = term expressing degree of mixedness, and A_p = value of this term for perfect mixing, definitions of the latter also varying.

If A is defined as:	Graph of $\log\left[\frac{1}{1-A}\right]$ vs. r is:
$\frac{\sigma}{s}$	A straight line initially, then irregular.
s	Curved initially, then irregular.
Fraction of samples which have "approximately * the same composition" as the over-all mixture (6, 9).	A straight line can be drawn through the widely scattered points.
Fraction of samples which contain between 10 and 90% sand (12).	Graph is not possible. 100% mixing, according to this definition, after about 500 (varies with the run) rev.

* *Approximately* not defined. In order to test the data the authors defined *approximately* as follows: within the range of experimentally determined over-all mean-particle-fraction sand for the run ± 0.07.

Data from runs 1, 2b, and 3 used. Curves available in reference 13.

which contain between 10 and 90% sand. Neither of these methods of plotting gave a straight line in the early portion for all of the runs. (Bonilla, Crownover, and Goldsmith's method was tested for run 1; Visman and Van Krevelen's method, for runs 1, 2b, and 3.) However, because the logarithmic and probability scales, used by the aforementioned authors respectively, stretch out the early portion of the graph, more data in this portion would be required to establish clearly how the curve behaves there. Graphs for the foregoing data and a more detailed discussion are available elsewhere (*13*).

Notation

Symbols used here are those of the authors of each paper. They apply only to Table 4.

Brothman, Wollan and Feldman

y_t = proportion of the maximum theoretically possible surface of separation, S_p, that has been developed in t units of time
ϕ = constant of proportionality
P_t = proportion of the total number of cubes into which the mixture has been divided containing at least one element of the surface of separation
k = a constant
$c = \log \frac{1}{1-\phi}$

Coulson and Maitra

S = interfacial area of surface per unit volume of the mix
S_o = maximum surface per unit volume that can be achieved with the given system
t = time
k = a constant of proportionality
X = percentage that is unmixed; experimentally determined as follows: "To examine the extent of mixing some 30 samples were withdrawn from different positions in the drum by means of a sampling device, and the samples examined with an eye lens. "In the present investigation, if n samples out of 30 are found to have approximately the same composition as in the whole system then the mixture has been defined as $n/30 \times 100$ per cent mixed." (*6*) $X = 100 - n/30 \times 100$

Bonilla, Crownover, and Goldsmith

a.d. = mean deviation of the weight fractions of the "key constituent" for about five 5-g. samples

$$\text{a.d.} = \frac{\sum_{i=1}^{N} | c_i - \bar{c}}{N}$$

c_i = weight fraction of key constituent in *ith* spot sample
$\bar{c}$ = arithmetical mean value of c for the N spot samples
N = number of spot samples
c = weight fraction of the key constituent in the entire batch
r = number of revolutions of the mixer

Visman and Van Krevelen

100-Z = percentage unmixed; experimentally determined as follows: A number of samples are removed. If a sample does not show any visually observable mixing when examined with a magnifying glass, it is considered unmixed. The number of these unmixed samples divided by the total number of samples and multiplied by 100 is 100-Z. ". . . samples which show visible mixing, are defined as samples with more than 10% and less than 90% coal or salt.

Table 4.—Proposed Rate Equations and Plotting Methods

Investigator	Original rate equation proposed in derivation of final equation	Final equation given
Brothman, Wollan, and Feldman (3)	$y_{t+1} = y_t + \phi(1 - y_t)$	$P_t = 1 - e^{-kSp(1-e^{-1c})}$
Coulson and Maitra (6, 9)	$\frac{dS}{dt} = k(S_o - S)$	$\ln \frac{100}{X} = kt$
Bonilla, Crownover, and Goldsmith (2)	Not given	Data plotted as $-\log \frac{\text{a.d.}}{2c(1-c)}$ vs. $\log r$
Visman and Van Krevelen (12)	Not given	Data plotted as $(100 - Z)$ vs. t on linear probability paper using the probability scale for $(100 - Z)$
Weidenbaum and Bonilla	$\frac{d\left(\frac{\sigma}{s}\right)}{dt} = k'\left[\left(\frac{\sigma}{s}\right)_{eq.} - \left(\frac{\sigma}{s}\right)\right]$	$\ln\left[\frac{1}{\left(\frac{\sigma}{s}\right)_{eq.} - \left(\frac{\sigma}{s}\right)}\right] = \ln\left[\frac{1}{\left(\frac{\sigma}{s}\right)_{eq.} - \left(\frac{\sigma}{s}\right)_o}\right] + k't$

Note: $\left(\frac{\sigma}{s}\right)_{eq.} = 1$

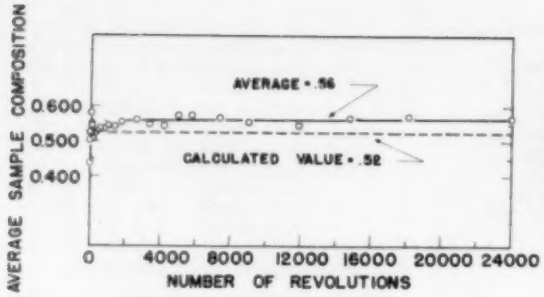

Fig. 12. Comparison of experimental average sample compositions with value calculated from known weights of salt and sand and particles per gram of each. Data of run 1 used. Sample composition expressed as particle fraction sand.

The samples which do not show visually observable mixing, are thought to contain less than 10% coal or salt." (*12*).

t = time

Weidenbaum and Bonilla

$\frac{\sigma}{s}$ = degree of mixing (terms defined under section on Degree of Mixing)

$\left(\frac{\sigma}{s}\right)_{eq.}$ = value of σ/s for theoretical random equilibrium mixture ($=1$).

k' = a constant

t = time [In the present work r(= number of revolutions) was used instead of time. The relation between the two for any rev./min. is obvious.]

SAMPLING BIAS

For proper analysis of data, any bias introduced physically by the method of sampling should be known. Figure 4 shows that the experimentally determined histogram peak for run 1 is displaced to the right of the peak of the theoretical distribution. This illustrates that the experimental sample compositions (expressed as particle-fraction sand) cluster about a different mean from that calculated by use of the weights of salt and sand put into the batch and the experimentally determined values of particles per gram for each of these. Figure 12 shows the experimental value to be 0.04 greater than the calculated one. Similar discrepancies were found for runs *2b* and 3, indicating a preference for the sand particles to fall into the pits in the sampling rod. This may be due to differences in physical properties, particularly particle shape and surface roughness and/or the shape of the pits in the sampling rod. The differences between the theoretical standard deviations computed for mean compositions of 0.52 and 0.56 are very small.

COMPARISON OF THE SAMPLING METHODS

Runs *2a* and *2b* permit a comparison of the two different methods of sampling, the former using nine spot samples of approximately 0.83 g. (about 14,500 particles) each per point and expressing compositions as weight fractions, and the latter using twenty-seven spot samples of approximately 120 to 160 particles each and expressing compositions as particle fractions. Figure 13 shows that although the curves are similar, the smaller spot samples give a consistently higher standard deviation * than the larger ones. Figure 14 illustrates a considerable difference in the values of $\log [1/1 - \sigma/s]$ reflecting large differences in the value of σ/s. σ decreases considerably more than s in going to larger samples. Thus, the ratio of σ/s for the larger samples is considerably less than that for the smaller ones and consequently, the graphs of $\log [1/1 - \sigma/s]$ differ as shown.

This helps to illustrate the complex nature of the term *state of mixedness*, in particular when applied to a partially mixed batch. Both sets of samples were taken from essentially the same mixture, the only difference being that the large samples were taken first and then the mixer was turned about 30° to take the small ones. Nevertheless, if only the standard deviation or $\log [1/1 - \sigma/s]$ were looked at, the two methods of sampling would give different impressions of the extent of mixedness and its rate of change.

* A method of converting from weight-fraction standard deviation to particle-fraction standard deviation is given in (*13*).

Summary

A procedure for following the course of a solids mixing operation in terms of the distributions of spot-sample compositions has been given and illustrated with experimental data. With this as background the operation of solids mixing has been defined in terms of the distribution of sample compositions approaching a theoretical limiting distribution, the binomial, for a randomly mixed batch. The use of the chi-square test for evaluating how close any mixture comes to a randomly mixed batch has been illustrated and a scale suggested for classifying mixtures as *excellent, good, fair, poor,* or *very poor* on a common basis. Degree of mixing has been defined as the ratio of a theoretically calculated standard deviation for the randomly mixed batch to the experimentally determined standard deviation among spot samples. These techniques and methods have been applied to follow and study the mixing of −40/+50 (U.S.) mesh salt and sand in a horizontal right-angle cylinder, approximately one third full, rotating about its axis. In addition, a rate equation has been proposed and tried with the preceding experimental data. It was found to hold in the early portion of the mixing operation, later deviation being attributed to an axial segregating driving force which works against the mixing driving force of random motion. This was shown to give, after long periods of mixing, a mixture with a higher sand concentration in the center of the mixer than near the ends. This phenomenon was attributed to tumbling differences between the two kinds of particles plus the tumbling surface curvature which occurs at the ends causing one type of particle to have a larger horizontal com-

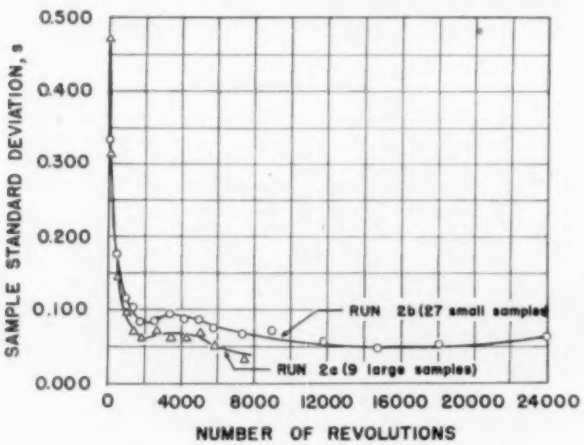

Fig. 13. Comparison of sample standard deviation, s, vs. number of revolutions graphs for two different methods of sampling.

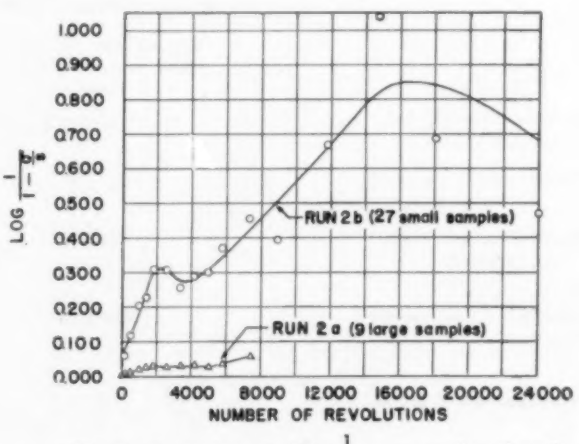

Fig. 14. Comparison of $\log \frac{1}{1 - \frac{\sigma}{s}}$ vs. number of revolutions graphs for two different methods of sampling.

ponent of motion toward the center than the other. The implications of this are that mixing for an infinite time does not necessarily give a thorough mixture even if particle size and density of the two materials are close together. It seems reasonable that similar segregating tendencies will take place in other tumbling mixing operations where there are differences in tumbling properties and surface curvature near the end. It is recommended that those using this type of apparatus methodically check to see whether this axial segregating effect is present and if so to what extent it causes unmixing. Although these phenomena may be difficult to study in actual industrial practice, small-scale experiments with the aforementioned techniques on dimensionally similar models offer a way of studying the mixing operation with an eye toward correcting the physical phenomena which hinder good blending. Correlation of mixer and particle properties with the extent of segregation could be studied for various systems as a basis for future improvements in mixer design and/or preparation of materials to achieve good mixing.

It would seem as though the directions of work for remedying axial segregating tendencies such as found here are 1) preparation of materials so as to minimize angle of repose differences where posible, 2) design of mixer so as to minimize curvature of the mixture surface, 3) employment of a mixing motion which is primarily throwing the particles and not rolling them down a surface. 4) Employing forced three dimensional motion of the particles.

Experimental work on two different methods of sampling illustrated the ambiguity as to the true state of a mixture if only a "degree of mixing" is stated without complete details on how this number was obtained. Several degrees of mixing and rate equations or methods of plotting previously proposed were compared.

Appendix (see 13)

I. CHI-SQUARE TEST

1. As Test of Significance. For purposes of illustration the chi-square test is performed with data from run 1 although the mixture is known to be nonrandom owing to the previously discussed segregating effect.

Before this can sensibly be applied to the data it is necessary to correct for the sampling bias previously mentioned. This is done by subtracting 0.04 from each of the eighty-one values of particle-fraction sand and using the resultant values for the chi-square test. (This method of correcting is not perfect since the bias might vary with the magnitude of particle-fraction sand.) The relative-frequency histogram based on the corrected values is then compared with the frequency distribution for a theoretically randomly mixed batch for the conditions of run 1.

Before the chi-square test is applied it is necessary to determine the standard deviation of m and σ (see Figure 6) as these parameters are based on experimentally determined quantities.

The values of m and σ depend on the following:

(1) particles of sand per gram of sand $= \eta_{sn}$
(2) particles of salt per gram of salt η_{sl}
(3) number of particles per spot sample $= n$
(4) weights of sand and salt in the batch, W_{sn} and W_{sl}, respectively.

(1) and (2) in turn depended on (*a*) a counted number of each type of particle and (*b*) weighings before and after the salt particles are washed out. Since six separate determinations of (1) and (2) were made, the mean ($\bar{\eta}$) and variance (σ_η^2) could be computed in each case. Also the mean and variance were determined for n. The error in weighing 696 g. of salt and 930 g. of sand on a torsion balance accurate to 0.1 g. was considered negligible compared with the variations in η_{sl}, η_{sn}, and n.

From the foregoing information the variance of m and σ can be calculated:

$$m = p = \frac{\eta_{sn} \cdot W_{sn}}{\eta_{sn} \cdot W_{sn} + \eta_{sl} \cdot W_{sl}} \qquad (7)$$

By use of the propagation-of-error equation,

$$\sigma_m^2 = \left(\frac{\partial m}{\partial \eta_{sn}} \sigma_{\eta_{sn}}\right)^2 + \left(\frac{\partial m}{\partial W_{sn}} \sigma_{w_{sn}}\right)^2 + \left(\frac{\partial m}{\partial \eta_{sl}} \sigma_{\eta_{sl}}\right)^2 + \left(\frac{\partial m}{\partial W_{sl}} \sigma_{w_{sl}}\right)^2 \qquad (8)$$

From which $\sigma_m^2 = 0.00004196$ and $\sigma_m = 0.0065$.

If similar equations for the propagation of error are used to determine the variance of

$$\sigma = \sqrt{\frac{p(1-p)}{n}}, \qquad (9)$$

Then:

$$\sigma_\sigma = \left(\frac{\partial \sigma}{\partial_p} \sigma_p\right)^2 + \left(\frac{\partial \sigma}{\partial n} \sigma_n\right)^2 \qquad (10)$$

$\sigma_p = \sigma_m = 0.0065$

For σ_n the authors used an experimentally determined standard deviation of n based on eighty-one values used for the chi-square test (twenty-seven values of n at each of the following numbers of revolutions: 14,798, 18,113, and 24,021).

$\sigma_n = 12$

from which

$\sigma_\sigma^2 = 3.9107 \times 10^{-6}$
$\sigma_\sigma = 0.002$

The preceding calculated standard deviations of the parameters m and σ which are necessary to compute the normal approximation must be taken into account when the chi-square test is performed. $m \pm 2\sigma_m$ and $\sigma \pm 2\sigma_\sigma$ can yield many different combinations of m and σ which will give different results when the chi-square test is performed. If some combinations of m and σ show significant chi-square results and others do not, as will be shown to be the case here, then the problem is more complicated and requires further statistical study which has not been gone into here. The basic idea, however, is illustrated by giving the values of chi-square for five different combinations of m and σ which are all within the range of $m \pm 2\sigma_m$ and $\sigma \pm 2\sigma_\sigma$

$m = 0.526 \quad 2\sigma_m = 0.013$

$\sigma = 0.043 \quad 2\sigma_\sigma = 0.004$

If $m =$	and $\sigma =$	then chi-square equals	which at 95% level of significance is
0.526	0.043	5.05	not significant
.513	.047	13.68	significant
.513	.039	25.74	significant
.539	.047	3.34	not significant
.539	.039	10.83	significant

NOTE:–In the foregoing chi-square tests three class intervals were used in order that each class interval might give an expected frequency $\geqslant 5$. Thus, chi-square has two degrees of freedom.

Since the magnitudes of the standard deviations of m and σ prevented a clear-cut statistical decision from being made here via a simple chi-square test, future work of this sort should focus attention on diminishing the experimental variations which caused them.

2. As Method of Evaluating Mixture. For purposes of illustration, the mixture classifications corresponding to the five previously given values of chi-square are given below.

Chi-square	Relative frequency of occurrence of chi-square for 2 degrees of freedom	Call mixture (See Table 2)
5.05	between 0.05 and 0.10	very poor
13.68	less than 0.005	very poor
25.74	less than 0.005	very poor
3.34	between 0.10 and 0.20	poor
10.83	less than 0.005	very poor

Thus, despite the experimental variations, this method of classifying mixtures gives a description of very poor–poor for the mixture obtained in run 1 after a long mixing time. This is satisfactory intuitively because it is known from previous work that the axial segregating effect prevented the batch from becoming well mixed.

II. AXIAL SEGREGATING EFFECT–STATISTICAL APPROACH

As previously mentioned, after a long mixing time an axial sand concentration gradient was found (Figure 9). Further information on this condition can be obtained by comparing the experimental values of standard deviation among the samples within any section with the theoretical-section standard deviation and the over-all experimental and theoretical standard deviations. The theoretical section standard deviation can be estimated from the estimate of section mean and the average number of particles per spot sample by use of the formula for the standard deviation of a binomial distribution. For any section

$$\sigma_{ss} = \sqrt{\frac{\left(\frac{\bar{x}}{n}\right)_{ss}\left(1 - \left(\frac{\bar{x}}{n}\right)_{ss}\right)}{n_{ss}}} \qquad (11)$$

Table 5.—Experimental Standard Deviation by Sections and Over-all Experimental Standard Deviations

Average section theoretical standard deviation = 0.042 = average over-all theoretical standard deviation.

Run 1a had glass beads; others did not.

Run	No. of revolutions	Sections (see Figure 9)									
		1	2	3	4	5	6	7	8	9	Over-all
1	14,800; 18,100; and 24,000	0.032	0.045	0.028	0.042	0.036	0.037	0.029	0.041	0.046	0.055
2b		.027	.058	.035	.028	.038	.020	.048	.046	.040	.055
3		.053	.050	.040	.060	.043	.043	.038	.062	.030	.086
1a	46,121; 49,316; and 52,264	.039	.046	.039	.055	.045	.033	.047	.030	.051	.052
Avg.		.038	.050	.036	.046	.040	.033	.040	.045	.042	.062

where

σ_{ss} = estimated theoretical section standard deviation

$\left(\frac{\bar{x}}{n}\right)_{ss}$ = mean particle-fraction sand in the spot samples taken from the section

n_{ss} = average number of particles per spot sample for the section

Note that for the same n_{ss}, even a rather large change in the value of $(\bar{x}/n)_{ss}$ does not greatly change the value of σ_{ss}. Differences in the values of n_{ss} and $(\bar{x}/n)$ for different sections and different runs will cause some variation in the estimated theoretical section standard deviation. The average σ_{ss} for the nine sections and different runs shown in Table 5 was 0.042 with a range of 0.039 to 0.045. Data from run 1a are included, although it is realized that the presence of glass beads in this run makes it different from the others. If the values for any section are averaged over all four runs, the values of the mean section σ_{ss} range from 0.040 to 0.044.

These results show conclusively that the variation among sample compositions within a section is less than the over-all variation between samples. If desired, the state of the mixture within any specific section can be determined via the chi-square tables and Table 2 by the use of the sample compositions from that section only and the procedures previously described.

Acknowledgment

Thanks are due to R. H. Bechhofer, L. Cote, and J. Kiefer for guidance on the statistics and to R. Wonn for later statistical help; to J. F. Pardo for miscellaneous suggestions; to Chai Sung Lee for Japanese translations for the literature review; to G. Trost for equipment construction; to S. G. Salzinger for photographs; to Columbia University, for the Goldschmidt and Barnard Fellowships; and to Mrs. Sherman Weidenbaum for general help, including typing. Also, a debt is due the Corning Glass Works for the encouragement and interest which played a large part in transforming this work from dissertation to publishable form.

Notation

x = number of sand particles in a spot sample

n = total number of particles in a spot sample

$f\left(\frac{x}{n}\right)$ = normal distribution probability; an approximation (more easily calculated) of the binomial distribution probability (see 13).

p = true particle-fraction sand in the mixture = mean of binomial distribution

m = mean of normal distribution (equal to p since normal distribution is being used to estimate binomial distribution)

A = extent of mixedness in a certain type of rate equation; defined differently by various people. See Table 3.

A_p = value of A for a "perfect" mixture, definitions of "perfect" also differing

t = time

r = number of revolutions of the mixer

k', K = constants as defined by their respective rate equations

N = number of spot samples taken from the mixture at any sampling

$-$ = an arithmetical mean value when placed above a symbol

SUBSCRIPT

i = the *ith* sample

STANDARD DEVIATION

In connection with randomly mixed batch:

s = experimentally determined sample standard deviation [Equation (2)]

σ = theoretical standard deviation for a randomly mixed batch based on the proportions of sand and salt particles originally put into the mixture [Equation (9)]

σ_{ss} = theoretical standard deviation based on the proportions of sand and salt particles in any section after long mixing [Equation (11)]

In connection with experimental error (Appendix I).

$\sigma_{\eta_{ss}}$ = (read the standard deviation of η_{ss}) = the standard deviation among values of η_{ss} used in the propagation-of-error equation [see Equations (8) and (10)]. Estimated from experimental measurements; σ's for other quantities defined similarly.

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application of strain gauge devices in the process industries

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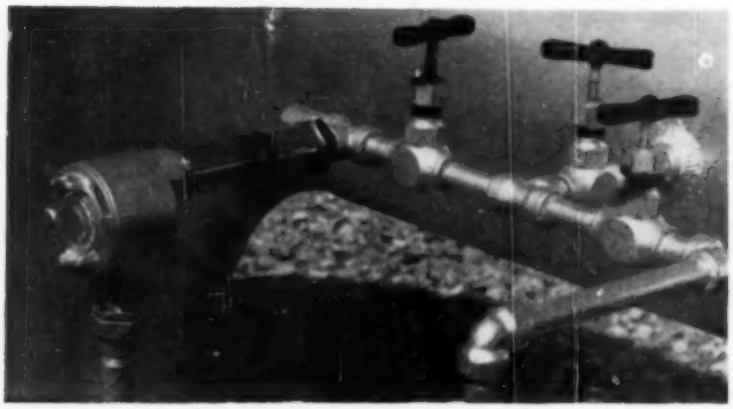


Fig. 1. An SR-4 pressure cell in use at a pipeline pumping station for transmitting pipeline pressures electrically to a central control panel for telemetering signals to central control stations.

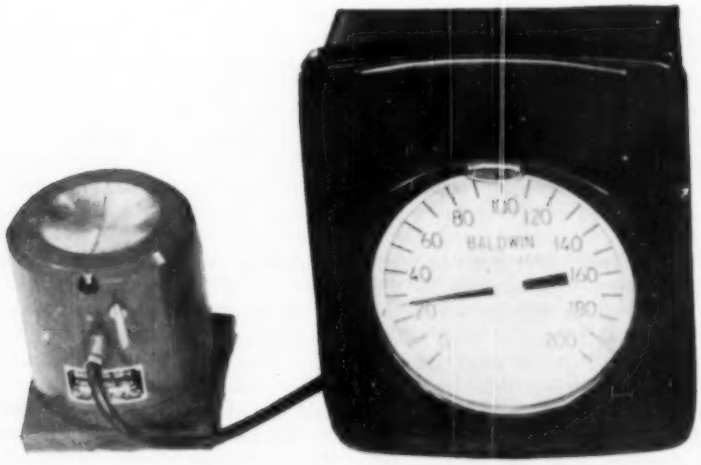


Fig. 2. SR-4 load cell connected to Baldwin load indicator.

The development of bonded resistance wire strain gauges in its early stages had a marked effect on and was greatly affected by the simultaneous expansion of the airplane industry. The gauges were used by the hundred thousand on airplanes in the need to know exact stresses at doubtful points so as to pare safety factors to the bone and increase the bomb load or speed of military aircraft. Accuracies required were low at first, but as safety factors became smaller the gauges and techniques for their use were necessarily improved. At the same time laboratory personnel in many fields eagerly accepted the new tool and demanded greater quantities and more important, greater variety and increased accuracy.

Soon the strain gauge was used for a different purpose—still to measure strain, but this strain (and resultant resistance change) to be interpreted as a measure of a physical quantity. Such a device, which provides an electrical signal proportional to a change in a physical quantity, is known technically as an electrical transducer and colloquially as a pickup or cell. Probably the first such transducer was a torque pickup but other types—pressure cells and load cells—followed quickly. Improvements in the transducer gauges provided more accurate indication and in turn necessitated improvements in transducer design to provide the isolation from extraneous environmental forces which is necessary to the high accuracy and reliability characteristic of pickups using the bonded resistance wire gauge principle.

The transducer gauge is a very thin sandwich of strain-sensitive wire between two thin sheets of paper, all held together by a phenol resin (Fig. 3). The greatest difference between the transducer gauge and the corresponding stress analysis gauge is that in the stress analysis gauge the resin is polymerized to hold the whole sandwich together until the technician cements it to his specimen, whereas the transducer gauge is polymerized in place on the element. This single-step operation bonds the gauge more intimately to the surface and provides more faithful response to the strain of the sensitive member.

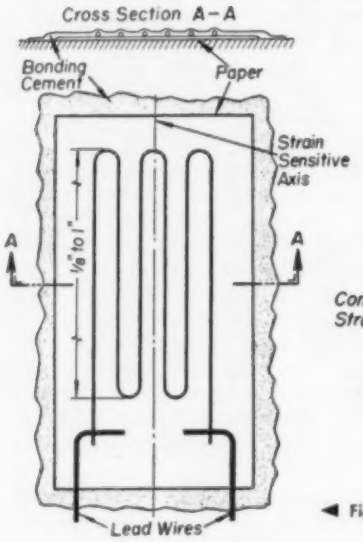
Obviously, the close control necessary for this polymerization step is seldom available in the field use of strain gauges and, in fact, the faithfulness of response which such a method affords is seldom necessary either. There are other differences between the two families of gauges—choice of wires, type of bonding resins, thickness of supporting paper, etc.—all dictated by the quite different characteristics required by dissimilar uses.

Instrumentation

During the early development of resistance-type strain gauges the only common means available for sensing the minute changes in resistance were high-sensitivity light beam galvanometers. At the present time nearly all industrial-type electronic instrumentation may be used with wire resistance type strain gauges and, of course, with the transducers or pickups using these gauges for a sensing element.

The Wheatstone bridge and its modifications had for the last century been used for accurate measurement of resistance, and so it was natural for it to be adapted to the needs of the resistance strain gauge. The resistance bridge is still basic to resistance measurements in general, invaluable to the resistance strain gauge, and the mainstay of the precision of the resistance gauge pickup, cell, or transducer. In an SR-4 pickup four gauges are bonded to the element and wired into a complete bridge. The four gauges are generally wired so that the load, pressure, or torque acts to increase the resistance of two opposite arms at the same time that it is decreasing the resistance of the other two opposing arms. It is then necessary only to apply a voltage across opposite corners of this bridge and measure the resulting voltage output from the other two corners. The voltage measurement is usually made by comparing this voltage output to that from a similar bridge within the instrument produced by a calibrated slide wire so that it is always a known quantity. When the two resistance bridges are connected together in such a way that their voltage outputs oppose each other, a sensitive current-indicating device will indicate exact equality of the two voltages when no current flows. This device may be a galvanometer or an amplifier and meter, high sensitivity being the only requirement. This general method of measuring is known as the null-balancing or no-current-flowing system and is very useful because its accuracy is not dependent on the accuracy, linearity, or gain of the galvanometer or amplifier. For practical use the calibration on the slide wire in the instrument bridge is usually in terms of strain in the gauge, load on the dynamometer, or other useful quantity so as to make the instrument direct-reading.

The resistance change of the gauges is very small, the units generally used are micro-ohms, and the bridge voltage outputs are generally measured in millivolts for full capacity output. Because these signals are so small that nothing except the more sensitive laboratory instruments can measure them directly, the use of instrumentation of the null-balancing (comparison) type in conjunction with high-gain amplifiers is essential.



◀ Fig. 3. Schematic drawing of basic strain gauge element.

Torque Measurements

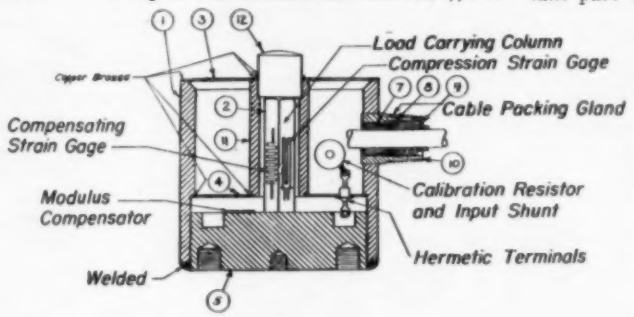
The torquemeter, probably the most straightforward of the SR-4 bonded resistance wire transducers or pickups, consists of a short section of shaft to a portion of which are bonded the sensing gauges. These gauges are applied at the 45° angles in which the maximum strain due to torsion is found. Four gauges are applied and wired into a bridge circuit, the corners connected to four sliprings on the shaft. A nonrotating brush assembly (sometimes supported by ball bearings on the same shaft) provides contact with the sliprings to make connection to the measuring instrument.

When the pickup is connected into a line of shafting that carries power, the shaft twists exactly proportionally to the torque, regardless of the speed, causing the gauges to change resistance. This provides a voltage output from the energized bridge just as do other pickups.

This type of pickup is used to measure input to and output from all sorts of rotating machinery. Mixing Equipment Company uses a complete series of torque pickups in the laboratory to determine the size motor to install in a mixer for each particular use. Another company employs such pickups in the mixing shafts of production kettles to keep a continual record of and watch over the progress of the mix. Such a pickup avoids the necessity for breaking the vacuum and sampling, a very time-consuming business, provides much greater accuracy than can be obtained by measuring motor input power, and puts the indication in the control panel, where it can be continually observed. A few trials give the operator a very good indication of the torque reading at which he should stop the reaction. The step to an automatic shut-off is, of course, an obvious and easy one. Small capacity pickups are also used in the laboratory and pilot plant to pre-determine the mixing requirements of a process.

Control of the loading of a Bird centrifuge is accomplished by a measurement of torque but in a somewhat different manner. In this case the stationary gear of a planetary gear system controlling the feed is kept from rotating by means of a cantilever beam. Gauges on the beam provide an electrical signal proportional to the force preventing rotation. This signal actuates a feed valve controller which maintains a constant load in the centrifuge. Automatic control prevents jamming and resultant long shutdowns and still allows the units to be run at full capacity. One man can attend a considerable number of such units.

▼ Fig. 4. Cross section of SR-4 load cell, type C.



Weight Measurements

Weighing is, of course, a very important part of every process. Load cells, shown in cross section in Figure 4, make the weighing easy and substitutions such as volumetric measurement, unnecessary, and bring the indication and control right to the control panel, where they belong.

The sensing element consists of a load-bearing column to which the resistance wire strain gauges are bonded in such a manner as to be sensitive to tension (or compression). Around the column are guiding diaphragms in a rugged case to protect the sensing element from physical harm, chemical attack, and all forces other than that which it is designed to measure. A cable extends from the case to provide connection to the instrument, Figure 2.

These cells may be used singly to hang a small weigh tank or in combination to support larger tanks or even a complete reaction kettle or digester. Figures 5 and 6 show load cells supporting a sand bucket in a foundry and a hopper in a chemical plant. As with any other method of weighing, the container to be weighed must be reasonably isolated from forces which are not a function of weight. However, since the cells are very low deflection devices, this isolation usually is not much of a problem.

The particular advantages, above the main one of electrical remote indication, are the ease of protection and absence of maintenance which are provided by the rugged, hermetically sealed load cell. This is not to be construed, however,

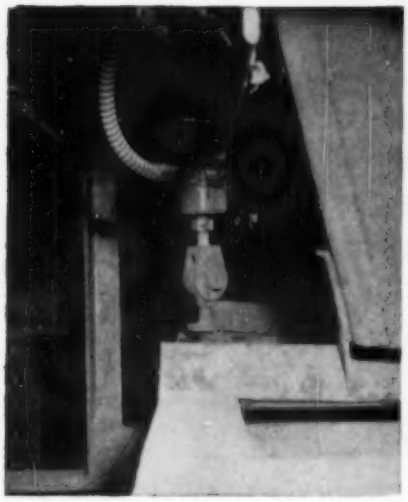


Fig. 5. This SR-4 load cell is used in weighing a mold sand bucket in a foundry. Two or three types of sand are weighed into the bucket automatically.

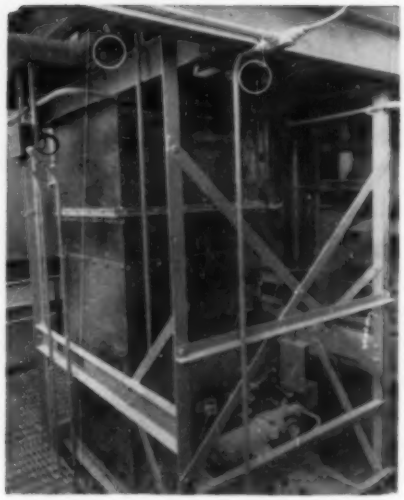


Fig. 6. The two SR-4 load cells, which are circled, support a hopper which will automatically batch preset weights of materials into railroad cars for shipping.

as an indication that it is necessary only to buy a load cell and set a tank on it. Unless the application is of the simplest type, each different system should be engineered by someone familiar with the characteristics and uses of the cells. This is all the more true because load cell weighing, being somewhat of a novelty, is most often used where the conditions are too severe for other systems.

Since the output of the cells is electrical, this output can be fed into most types of electronic instrumentation to make available the convenience and service economy of the same brand of instrumentation throughout a process and an extensive line of controls ranging from simple on-off control to proportional control with reset and derivative action and from simple timers to elaborate program types with variable flow rates. Load cell installations in Figures 5 and 6 provide varying degrees of automatic control. The usual 1% control accuracies are easily obtained and maintained and, where necessary, much higher accuracies can be obtained, usually by fairly extensive modification of the standard electronic instrumentation. A track scale installed at Baldwin-Lima-Hamilton about two years ago utilizing SR-4 load cells for the weighing elements has been calibrated repeatedly by the National Bureau of Standards and the individual railroads concerned and found at all times to be well within 1/10% accuracy even at loads of less than 1/10 of capacity. Such a scale has been used for weighing-out of railroad tanks cars used as storage tanks outside processing plants.

Pressure Measurements

In general a pressure cell consists of a hollow metal tube with one end closed and with strain gauges firmly bonded to the outside. As pressure increases inside the tube, the resultant strain on the outside is measured by the gauges. As in load cells, the gauges are wired into a bridge circuit, the output of which is set to a nominal figure. The gauged portion is protected by a heavy metal cover, which also provides a hermetic seal, Figure 7.

The problems encountered by pressure cells are considerably different from those met by load cells. The main design difficulty here is that of corrosion. High output from a tube-type pressure cell presupposes high stresses. Accuracy and repeatability depend on good elastic properties, but no material seems available with high strength, good elastic properties, and the ability to resist attack from all, most, or even many of the compounds ingenious chemical engineers prepare and use.

For the cases where the 400-series of stainless steels provides adequate corrosion resistance, SR-4 pressure cells of the hollow-tube type in capacities from 200 lb./sq.in. to 50,000 lb./sq.in. are available. Beryllium copper is used for a tube material in high pressure processes where there is a possibility of free hydrogen. Unfortunately the 300-series of stainless steels, which has rather good corrosion-resistant properties, has such poor elastic properties that hollow-tube-type pressure cells are not generally fabricated from it. For those cases where a 300-series stainless steel is necessary, a different design is needed. A bellows is used to contain the pressure; this bellows is restrained by a cantilever beam to which the strain gauges are bonded so as to measure the force exerted by the bellows. The poor elastic properties of the bellows in such a construction have little influence on the performance of the gauges, which are attached to the beam of high-strength material having no need of corrosion resistance.

Great numbers of pressure cells have been used in the combustion chambers of rocket motors to measure burning pressures and rates. The cells have also been used extensively on oil pipeline pumping stations in service which previously had caused Bourdon gauges to give up after a few weeks. In such

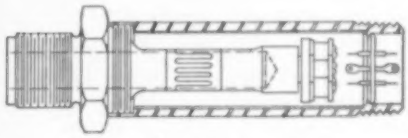


Fig. 7. Hollow tube pressure cell.

service, in addition to the ruggedness which pares maintenance costs nearly to zero, the electrical pressure cell has the added extreme advantage of keeping inflammable and explosive fluids out of the control room. Since it is hermetically sealed, the pressure cell can be—and often is—installed outdoors with no protection from weather. The provision of an electrical output signal allows the use of complete automatic control and also makes for easy telemetering of the signal. Several unattended pumping stations are now in operation. (Fig. 1)

Unlike load cells, pressure cells require no extensive pre-engineering. The cells are simply screwed into the container in which the pressure is to be measured and electrical cable is run from the cell to the indicating, recording, or control instrument. The same instruments (indicating, recording, or controlling) can be used with the pressure cells as with the load cells; in fact, an instrument could be fitted with a selector switch to use either.

Low capacity pressure cells are sometimes used in deep tanks to measure level. Remote indication in this case permits complete control of a tank farm from a single location.

The use of an electrical pickup providing a standard signal proportional to load, pressure, or torque (whichever is to be measured) allows instantaneous, remote indication, recording, or control. Because of the present trend of the process industries toward centralization and the resultant crowding of panel boards, the possibility of using a single recorder and switching into it a number of variables becomes attractive. The standard electrical output provided by these pickups becomes a necessity in the light of the foreseeable future trend toward automation and the use of electronic calculators in the control loop.

Presented at New Jersey Section 1-Day Meeting, May 11, 1954.

TRENDS OF FUTURE PROCESSING

annual directory of chemical engineering theses

COMMENTARY

by Raymond H. Ewell—National Science Foundation

The number and pattern of theses in chemical engineering completed in 1954 did not change significantly compared with 1953. The January 1954 list included 140 theses, while the present list totals 136. The big fields of chemical engineering research continue to be kinetics, chemical processes, heat transfer, distillation, diffusion, and thermodynamics as in previous years. The influence of the atomic age is shown by theses on thorium recovery, promotion of chemical reactions with gamma radiation, separation of rare earths, and kinetic studies using radioactive isotopes. Current interest in the newer metals is illustrated by theses involving zirconium, hafnium, titanium, and calcium. The growing importance of the future resources problem is reflected in theses on catalytic cracking of shale oil, gasification of coal, flotation of cassiterite, and thermal decomposition of calcium sulfate. Continued interest in petrochemicals is reflected in theses on oxidation of hydrocarbons, ethylene polymerization, separation of close-boiling hydrocarbons, and synthesis of cycloöctatetrene.

EDITOR'S NOTE

This is the fourth successive year that CEP has offered a classification of the year's Ph.D. theses.† The same unit operations, and process descriptions appear as headings, such as Adsorption and Diffusion, and Heat Transfer and Mixing, plus new ones which did not appear in either of the preceding indexes—namely, Fibers, Flotation and Metallurgy. Again the suggestion is made that in using the index for a subject of interest, more than that specific subject be checked since a title can fall into more than one classification.

Absorption

ABSORPTION AND DESORPTION OF SLIGHTLY SOLUBLE GASES IN FALLING LIQUID FILMS WITH AND WITHOUT RIPPLING.* **Richard E. Emmert,** University of Delaware. Prof. R. L. Pigford. 97 pp. (June, 1954.)

ABSORPTION-OXIDATION PROCESSES IN DISPERSED MEDIA.* **L. Bryce Andersen,** University of Illinois. Prof. H. F. Johnstone. 162 pp. Two copies filed in university library. Microfilm 1¼ cts. a page. Abstracts and conclusions available separately. (June, 1954.)

KINETICS OF ABSORPTION AND CHEMICAL REACTION. **Norman W. Frisch,** Yale University. Prof. Harding Bliss, 208 pp. (June, 1954.)

Adsorption

ADSORPTION EQUILIBRIA OF OXYGEN AND NITROGEN. **Manfred Altman,** New York University. Profs. Frank Maslan and Morris Newman, 261 pp. One copy available in university library. (June 1954.)

ADSORPTION OF HYDROGEN AND CARBON DIOXIDE ON A NICKEL-KIESELGUHR CATALYST. **Leonard M. Napthali,** University of Michigan. Prof. R. R. White, 155 pp. One copy available from university library. Positive microfilm 1¼ cts. a page. (1954.)

THE ADSORPTION WAVE IN GRANULAR DESICCANT BEDS.* **Herbert M. Katz,** University of Cincinnati. Prof. William Licht, 123 pp. Two copies in university library. (June, 1954.)

LIQUID PHASE ADSORPTION STUDIES FOR THE SYSTEM BENZENE-*n*-HEPTANE-SILICA GEL. **David Hacker,** Northwestern University. Prof. Geo. Thodos, 143 pp. Microfilm available at 1¼ cts. a page. (September, 1954.)

SURFACE AREA MEASUREMENT OF SMALL PARTICLES BY LIQUID-PHASE ADSORPTION OF STEARIC ACID.* **Preston T. Bankston,** Georgia Institute of Technology. Prof. J. M. DallaValle, 73 pp. One copy available in Georgia Institute library. Photostats 35 cts. a page; microfilm 6½ cts. a page. (October, 1953.)

Aerosols

COLLECTION OF AEROSOLS BY FIBER MATS.* **James Bok Wong,** University of Illinois. Prof. H. F. Johnstone, 125 pp. Two copies available in university library. Microfilm available from University Microfilms, Ann Arbor, 1¼ cts. a page. (February, 1954.)

PROPERTIES OF AEROSOLS OF SOLID PARTICLE. **Sheldon K. Friedlander,** University of Illinois. Prof. H. F. Johnstone, 78 pp. Two copies available in university li-

* Work continuing.

† No copies of theses available in office of Chemical Engineering Progress.

brary. Microfilm available from University Microfilms, Ann Arbor, 1¼ cts. a page. (October, 1954.)

PROPERTIES OF ELECTRICALLY CHARGED AEROSOLS.* **Herbert F. Kraemer,** University of Illinois. Prof. H. F. Johnstone, 135 pp. Two copies available in university library. Microfilm available from University Microfilms, Ann Arbor, 1¼ cts. a page. (June, 1954.)

Chemical Processes

AN INVESTIGATION OF THE CATALYTIC VAPOR PHASE OXIDATION OF BENZENE. **James N. Holsen,** Washington University. Prof. D. F. Chamberlain, 195 pp. (June, 1954.)

AN OXIDE PROCESS FOR METALLIC CALCIUM. **W. D. Threadgill,** University of Missouri. Prof. F. D. Oldham, 100 pp. One copy in Engineering Branch of university library. Abstract available from chemical engineering department. (June, 1954.)

CATALYTIC CRACKING OF SHALE OIL BY DIRECT COKING ON A CONTINUOUSLY REGENERATED FLUIDIZED BED.* **George W. Walpert,** University of Colorado. Prof. Paul L. Barrick, 53 pp. Copy available from university library. (1953.)

CAUSTIC TREATMENT OF ZIRCON SAND.* **John B. West,** Iowa State College. Prof. G. H. Beyer, 116 pp. Two copies available in college library. Photostat 35 cts. a page; microfilm 2½ cts. a page ($1. minimum.) (August, 1954.)

CONTINUOUS OXYGEN-INITIATED ETHYLENE POLYMERIZATION.* **Frank N. Grimsby,** Massachusetts Institute of Technology. Prof. E. R. Gilliland, 255 pp. Filed in Hayden Library, M.I.T. Photostats and microfilm available from library. (February, 1954.)

CROSS-LINKING STUDIES ON POLYESTERS. **Leslie C. Case,** Massachusetts Institute of Technology. Profs. E. A. Hauser and H. P. Meissner, 65 pp. Photostats and microfilm available from Hayden Library, M.I.T. (June, 1954.)

EVALUATION OF CATALYSTS FOR HYDROCARBON OXIDATION. **John E. Anderson,** Iowa State College. Prof. G. H. Beyer, 88 pp. Two copies available in college library. Photostats 35 cts. a page; microfilm 2½ cts. a page ($1. minimum.) (December, 1953.)

FIXED BED CATALYTIC CRACKING OF OIL SHALE VAPORS FOLLOWING RETORTING IN A FLUIDIZED SYSTEM.* **Gustaf H. Panula,** University of Colorado. Prof. Paul L. Barrick, 96 pp. One copy available in college library. (1953.)

GASIFICATION OF WASHINGTON COAL.* **Louis M. Dvoracek,** University of Washington. Prof. R. W. Moulton, 65 pp. One copy available in main library of university. Photostat 30 cts. a page; microfilm 3 cts. a page. Conclusions available separately. (December, 1953.)

LOW TEMPERATURE PROCESS FOR THE PURIFICATION OF COTTON LINTERS. **Emerick J. Dobo,** University of Texas. Prof. K. A. Kobe, 150 pp. One copy available in university library. (June, 1954.)

MECHANISM OF WOOD PULPING BY THE KRAFT PROCESS. **G. R. Kulkarni,** University of Florida. Prof. W. J. Nolan, 108 pp. Copy available in engineering library of university. Photostat 25 cts. a page + $1.; microfilm $20. (June, 1954.)

MICRO-ARC PROCESS FOR SYNTHESIS OF ACETYLENE. **Robert L. Schaeffer,** Case Institute of Technology. Prof. George W. Blum, 126 pp. Copies available from Case library. Microfilm $1.50. Abstract and conclusions separately available. (June, 1954.)

PILOT PLANT PRODUCTION OF THORIUM FLUORIDE. **Norman Barson,** Iowa State College. Prof. Morton Smutz, 77 pp. Classified, copies not available. (July, 1954.)

PROMOTION OF SOME CHEMICAL REACTIONS WITH GAMMA RADIATION.* **John G. Lewis,** University of Michigan. Prof. Joseph J. Martin, 132 pp. One copy available from university general library. Positive microfilm 1¼ cts. a page. Abstracts and conclusions published in Microfilm Abstracts. (1954.)

THERMAL DECOMPOSITION OF CALCIUM SULFATE.* **Walter M. Bollen,** Iowa State College. Prof. G. L. Bridger, 193 pp. Two copies available in college library. Photostats 35 cts. a page; microfilm 2½ cts. a page ($1. minimum.) (June, 1954.)

Combustion

COMBUSTION OF DROPLETS OF HEAVY LIQUID FUELS.* **Hugh C. Simpson,** Massachusetts Institute of Technology. Profs. H. C. Hottel and G. C. Williams, 572 pp. Photostats and microfilm available from Hayden Library at M.I.T. (June, 1954.)

A STUDY OF THE CHARACTERISTICS OF OPEN TURBULENT FLAMES BURNING FROM TUBES.* **Leon B. Shore,** University of Delaware. Prof. Kurt Wohl, 94 pp. One copy available in Memorial Library of university. (June, 1953.)

Diffusion

DIFFUSION OF $C^{14}O_2$ IN MIXTURES OF $C^{12}O_2$—H_2 AND $C^{12}O_2$—C_3H_8. **Chan Hui Chou,** University of Michigan. Prof. J. J. Martin, 215 pp. One copy available from general library of university. Positive microfilm 1¼ cts. a page. Abstracts and conclusions published in Microfilm Abstracts. (1954.)

PART I. DIFFUSION IN LIQUID SULFUR. PART II. THE EFECT OF TEMPERATURE IN THERMAL DIFFUSION.* **Ronald L. Saxton,** University of Illinois. Prof. H. G. Drickamer, 212 pp. Two copies available in university library. Microfilm available from University Microfilms, Ann Arbor, 1¼ cts. a page. (February, 1954.)

THE EFFECTS OF THE MAJOR DESIGN AND OPERATION VARIABLES ON THE ENRICHMENT BY THERMAL DIFFUSION OF AQUEOUS SUGAR SOLUTIONS.* **Charles L. Kingrea,** Virginia Polytechnic Institute. Prof. F. C. Vilbrandt, 570 pp. Two copies available in V.P.I. library. Microfilm available at 7¼ cts. a page, from Universit; Microfilms, Ann Arbor. (July, 1953.)

HIGH PRESSURE THERMAL DIFFUSION.* **William M. Rutherford,** University of Illinois. Prof. H. G. Drickamer, 124 pp. Two copies available from university library. Microfilm available from University Microfilms, Ann Arbor. 1¼ cts. a page. (February, 1954.)

ISOMERIC EFFECTS IN THERMAL DIFFUSION.* **Elmer L. Dougherty, Jr.,** University of Illinois. Prof. H. G. Drickamer, 217 pp. Two copies available in university library. Microfilm available from Microfilms, Ann Arbor, 1¼ cts. a page. (November, 1954.)

MEASUREMENT AND GENERAL CORRELATION OF DIFFUSION OF NONELECTROLYTES: **Chang Pin,** University of California. Prof. Charles R. Wilke, 99 pp. One copy available in university library. Photostats 45 cts. a page; record print 20 cts. a page—$3.65. (February, 1954.)

OPERATION OF CONTINUOUS THERMAL DIFFUSION COLUMNS FOR LIQUIDS. **Thomas S. Heines,** University of Michigan. Prof. J. J. Martin, 114 pp. Filed in general library of university and graduate school office. Positive microfilm 1¼ cts. a page. Abstracts and Conclusions published in Microfilm Abstracts. (1954.)

SEPARATION OF AZEOTROPES BY MEANS OF DIFFUSION THROUGH POROUS MEMBRANES.* **Donald H. Hagerbaumer,** State University of Iowa. Prof. Karl Kammermeyer, 199 pp. Two copies available in university libraries. Photostats 10 cts. a page; microfilm 3 cts. a page. (February, 1953.)

STUDIES IN MEMBRANE SEPARATIONS.* **David Wm. Brubaker,** State University of Iowa. Prof. Karl Kammermeyer, 271 pp. Two copies available in university libraries. Photostat 10 cts. a page; microfilm 3 cts. a page. (June, 1953.)

THERMAL DIFFUSION IN AQUEOUS SOLUTIONS UNDER PRESSURE.* **Dario R. Cova,** University of Illinois. Prof. H. G. Drickamer,

107 pp. Two copies available in university library. Microfilm available from University Microfilms 1¼ cts. a page. (October, 1954.)

Distillation

EFFICIENCY AND MASS TRANSFER ON BUBBLE-CAP PLATES.* William F. Polich, Carnegie Institute of Technology. Prof. Carl C. Monrad, 231 pp. Two copies available from school library. (December, 1953.)

MOLECULAR DISTILLATION OF A COAL TAR PITCH FRACTION.* A. Katona, Case Institute of Technology. Prof. T. J. Walsh, 112 pp. One microfilm copy available from Case Institute, $1.50. (June, 1954.)

A NEW METHOD OF MEASURING FILM RESISTANCES IN DISTILLATION COLUMNS.* Dennis D. Foley, Ohio State University. Prof. Joseph H. Koffolt, 187 pp. One copy available at Inter-Loan Library of university with approval of advisor. Abstracts and conclusions will be separately available in about two years. (August, 1954.)

THE SEPARATION AND PURIFICATION OF C_{18} FATTY ACID METHYL ESTERS BY VACUUM FRACTIONAL DISTILLATION.* William R. Biles, Pennsylvania State University. Prof. Arthur Rose, 131 pp. Number of copies available from university library. (May, 1954.)

A STUDY OF FACTORS AFFECTING VACUUM FRACTIONATION IN A ONE FOOT DIAMETER PACKED COLUMN.* John H. Cusack, Pennsylvania State University. Prof. M. R. Cannon, 157 pp. Copies available in university library. (May, 1954.)

A STUDY OF NEW TYPES OF PHASE CONTACTORS.* Richard L. Heiny, Pennsylvania State University. Prof. M. R. Cannon, 138 pp. Several copies available from university library. (May, 1954.)

A STUDY OF OVERALL PLATE EFFICIENCY IN 1.83 AND 3 INCH DIAMETER PERFORATED PLATE DISTILLATION COLUMNS.* Charles L. Umholtz, University of Texas. Prof. M. van Winkle, 100 pp. One copy available at the university. Abstract available separately. (January, 1955.)

A THEORETICAL DISCUSSION OF STEADY AND UNSTEADY STATE MULTICOMPONENT RECTIFICATION INCLUDING A TREATMENT OF MIXTURES WITH AN INDEFINITE NUMBER OF COMPONENTS.* Andrew Acrivos, University of Minnesota. Prof. N. R. Amundson, 360 pp. (January, 1954.)

Drying

COMPOSITION CHANGE IN BINARY COMPONENT SPRAY VAPORIZATION AT ATMOSPHERIC PRESSURE.* James F. Culverwell, Northwestern University. Prof. George G. Lamb, 70 pp. Microfilm copy available from University Microfilms, Ann Arbor, 1¼ cts. a page. (October, 1954.)

EFFECT OF SEVERAL PROCESS CONDITIONS IN QUICK-CURING OF NORMAL SUPERPHOSPHATE.* John L. Kearns, Iowa State College. Prof. G. L. Bridger, 115 pp. Two copies available in college library. Photostat 35 cts. a page; microfilm 2½ cts. a page ($1. minimum.) (June, 1954.)

PILOT PLANT STUDIES OF QUICK-CURING OF SUPERPHOSPHATE.* Walter Drobot, Iowa State College. Prof. G. L. Bridger, 107 pp. Two copies available in college library. Photostat 35 cts. a page; microfilm 2½ cts. a page. (December, 1953.)

THE RATE AND MECHANISM OF DRYING OF WHEAT PARTICLES. Gino Sovran, University of Minnesota. Profs. Newman A. Hall and E. L. Piret, 100 pp. Copies available from university library. (June, 1954.)

SPRAYS IN HOT TURBULENT GAS STREAMS.* Clarke L. Coldren, University of Illinois. Profs. H. F. Johnstone and E. W. Comings, 315 pp. Two copies available in university library. Microfilm available at 1¼ cts. a page from University Microfilms, Ann Arbor. (June, 1954.)

Extraction

DISPERSED PHASE HOLD-UP IN PACKED COUNTERCURRENT, LIQUID-LIQUID EXTRACTION COLUMNS.* Charles E. Wicks, Carnegie Institute of Technology. Prof. Robert B. Beckmann, 129 pp. Two copies available in Institute library. (June, 1954.)

EXTRACTION, PURIFICATION AND PROCESSING OF CRUDE LACTIC ACID SOLUTIONS. Robert B. Weiser, Ohio State University. Prof. Christie J. Geankoplis, 138 pp. Copy available from Interlibrary Loan of university with approval of advisor. Abstracts and conclusions available in two years. (June, 1954.)

LIMITING FLOW RATES IN A SPRAY LIQUID-LIQUID EXTRACTION COLUMN. Wang-Mo Wong, State University of Iowa. Prof. James Osburn, 146 pp. Copies available from university Interloan Library. Microfilm 1¼ cts. a page. Abstract available in microfilm. (February, 1954.)

PHASE BEHAVIOR OF PROPANE-REDUCED CORNING CRUDE OIL SYSTEM. Augustus R. Van Kleeck, Ohio State University. Prof. Webster B. Kay, 62 pp. One copy available from university Interlibrary Loan with advisor's approval. Abstracts and conclusions available in two years. (June, 1954.)

PILOT PLANT EXTRACTION OF HAFNIUM FROM ZIRCONIUM. Robert Cox, Iowa State College. Prof. G. H. Beyer, 113 pp. Classified. (July, 1954.)

SEPARATION OF INDIVIDUAL RARE EARTHS BY LIQUID-LIQUID EXTRACTION FROM MULTICOMPONENT MONAZITE RARE EARTH NITRATES.* Julius H. Bochinski, Iowa State College. Prof. Morton Smutz, 89 pp. Two copies available from college library. Photostat 35 cts. a page; microfilm 2½ cts. a page ($1. minimum.) (March, 1954.)

SEPARATION OF THORIUM AND RADIUM-228 BY SOLVENT EXTRACTION. John Wiley, Iowa State College. Prof. Morton Smutz, 139 pp. Classified. (June, 1954.)

SOLVENT EXTRACTION OF MEAT AND FISH OFFAL.* Harold C. Arvidson, Jr., Iowa State College. Prof. L. K. Arnold, 107 pp. Two copies available in college library. Photostat 35 cts. a page; microfilm 2½ cts. a page ($1. minimum.) (March, 1954.)

Fibers

THE HISTOLOGY AND CHEMICAL COMPOSITION OF THE WOOL FIBER.* Richard L. Golden, Princeton University. Prof. John C. Whitwell, 160 pp. Two copies available from Firestone Library of university on Interlibrary loan. (June, 1954.)

STRESS RELAXATION OF FIBERS AS A MEANS OF INTERPRETING PHYSICAL AND CHEMICAL STRUCTURE.* Theodore Lemiszka, Princeton University. Prof. John C. Whitwell, 170 pp. Copies available on Interlibrary loan from Firestone Library of university. (July, 1954.)

Flotation

FLOTATION OF CASSITERITE BY ALKYL SUBSTITUTED NITRO PHENOLS AND NITRO RESORCINOL ETHERS.* Ishwarbhai Ashabhai Patel, Michigan State College. Prof. Clyde C. DeWitt, 65 pp. One copy available for loan from college library. (1953.)

Fluid Flow

AN EVALUATION OF A DYE DISPLACEMENT TECHNIQUE FOR VELOCITY DISTRIBUTION MEASUREMENTS IN LAMINAR FLOW.* James K. Ferrell, North Carolina State College. Prof. K. O. Beatty, Jr., 194 pp. One copy available in college library. Photostat—$75. (June, 1954.)

FLUID FLOW THROUGH ASSEMBLAGES OF SPHERES.* Norman Epstein, New York University. Prof. John Happel, 137 pp. Copies available from university library. Abstracts and conclusions available separately. (September, 1953.)

HORIZONTAL CO-CURRENT TWO-PHASE TWO-COMPONENT FLOW.* Philip D. White, University of Oklahoma. Prof. R. L. Huntington, 135 pp. Three copies available in general library of university. (1954.)

Fluid Mechanics

BUBBLE DYNAMICS.* **James C. Bryan,** University of Tennessee. Prof. Harold J. Garber, 105 pp. Several copies in university library and chemical engineering department. (June, 1954.)

THE EFFECT OF OPERATING VARIABLES ON SPRAYS PRODUCED BY A PRESSURE-TYPE NOZZLE. Joseph A. Consiglio, University of Michigan. Prof. C. M. Sliepcevich, 155 pp. One copy available from General Library of university. Positive microfilm 1¼ cts. a page. Abstracts and conclusions are published in Microfilm Abstracts. (1953.)

THE FLOW BEHAVIOR OF LOW TEMPERATURE LATEX.* **Shin-Ming Fok,** Case Institute of Technology. Prof. S. H. Maron. (September, 1954.)

FLUID FLOW PHENOMENA IN NATURAL CIRCULATION VERTICAL TUBE BOILERS.* **Girard E. Golden,** University of Delaware. Prof. S. A. Guerrieri, 68 pp. One copy available in university library. (June, 1953.)

SPECTRUM OF TURBULENCE IN AXISYMMETRIC FLOW.* **John E. Romano,** University of Illinois. Prof. H. F. Johnstone, 109 pp. Two copies available in university library. Microfilm available from University Microfilms, Ann Arbor, 1¼ cts. a page. (October, 1954.)

STUDIES IN THE RATE OF FALL OF DROPLETS.* **G. S. R. Narasimhamurty,** University of Cincinnati. Prof. William Licht, 152 pp. Copies available in university chemistry library. (June, 1954.)

TWO- AND THREE-DIMENSIONAL FLOW OF AIR THROUGH SQUARE-EDGED SONIC ORIFICES. Alexander Weir, Jr., University of Michigan. Prof. J. Louis York. One copy available from general library of university. Positive microfilm 1¼ cts. a page. Abstract and conclusions published in Microfilm Abstracts. (1954.)

Fluidization

MECHANISM OF HINDERED SETTLING AND FLUIDIZATION.* **Albert F. Loeffler, Jr.,** Iowa State College. Prof. B. F. Ruth, 119 pp. Copies available in college library. Photostat 35 cts. a page; microfilm 2½ cts. a page ($1. minimum.) (December, 1953.)

THE THEORY OF THE INTERRELATIONSHIPS BETWEEN TYPES OF VERTICAL FLUIDIZED SYSTEMS.* **Donald R. Flinn,** Princeton University. Prof. Joseph C. Elgin, 52 pp. Copies available on Interlibrary loan. (September, 1954.)

Heat Transfer

THE EFFECT OF PARTICLE SIZES, CONCENTRATION, AND TEMPERATURE ON HEAT TRANSFER TO CLOUDS OF SMALL PARTICLES.* **C. M. Oktay,** University of Florida. Prof. W. F. Brown, 150 pp. Copy available in engineering library of university. Photostat 25 cts. a page + $1.; microfilm $20. (January, 1955.)

THE EFFECT OF VIBRATION ON HEAT TRANSFER.* **Robert Lemlich,** University of Cincinnati. Prof. Wm. Licht, 137 pp. Copies available from university chemistry library. (June, 1954.)

HEAT TRANSFER CHARACTERISTICS OF NON-NEWTONIAN SUSPENSIONS.* **Jerome J. Salamone,** New York University. Prof. Morris Newman, 93 pp. Copy available from university library. (June, 1954.)

HEAT TRANSFER BY FREE CONVECTION TO FLUIDS CONTAINED IN VERTICAL TUBES. Charles V. Foster, University of Delaware. Prof. S. A. Guerrieri, 119 pp. Copy available from Memorial Library of university. (June, 1953.)

MASS TRANSFER IN A WETTED-WALL COLUMN. Eric R. Kent, University of Delaware. Prof. R. L. Pigford, 311 pp. Copy available from Memorial Library of university. (June, 1953.)

MEASUREMENT OF THE THERMAL CONDUCTIVITY OF MOLTEN LEAD.* **Murray W. Rosenthal,** Massachusetts Institute of Technology. Profs. W. H. McAdams and J. N. Addoms, 195 pp. Photstats and microfilm available from Hayden Library of M.I.T. (September, 1953.)

SIMPLIFIED CORRELATION FOR HEATING SOLID-AIR MIXTURES TRANSPORTED FROM A FLUIDIZED BED. William J. Carney, West Virginia University. Prof. H. P. Simons, 103 pp. Copy available from university library. (June, 1954.)

A STUDY OF HEAT TRANSFER TO LIQUID-SOLID SUSPENSIONS IN TURBULENT FLOW IN PIPES. Aven P. Miller, Jr. University of Washington. Prof. R. W. Moulton, 100 pp. Copy available from Main Library of university. Photostat 30 cts. a page; microfilm 3 cts. a page. Conclusions available separately. (December, 1953.)

THE TRANSIENT BEHAVIOR OF SINGLE-PHASE, NATURAL CIRCULATION LOOP SYSTEMS.* **Charles D. Alstad,** University of Minnesota. Prof. N. R. Amundson, 254 pp. (April, 1954.)

Ion Exchange

FACTORS INFLUENCING ELECTRO-IONIC SALT SEPARATIONS.* **Robert H. Farias,** Massachusetts Institute of Technology. Prof. E. R. Gilliland, 350 pp. Photostats and microfilm available from Hayden Library at M.I.T. (February, 1954.)

Kinetics

CATALYST STUDIES OF VAPOR PHASE ESTERIFICATION OF *n*-OCTYL ALCOHOL AND ACETIC ACID.* **Yerram Venkatesham,** Ohio State University. Prof Aldrich Syverson, 169 pp. Copy available from university library. Conclusions available about 1956. (November, 1953.)

DIFFUSION AND REACTION IN VISCOUS-FLOW TUBULAR REACTOR.* **Franklin A. Cleland,** Princeton University. Prof. Richard H. Wilhelm, 97 pp. Copies available from Firestone Library on Interlibrary loan. (May, 1954.)

THE HYDROGENATION OF CARBON MONOXIDE AND CARBON DIOXIDE ON A STEEL CATALYST.* **Buford Don Smith,** University of Michigan. Prof. R. R. White, 132 pp. Copy available from General Library. Positive microfilm 1¼ cts. a page. Abstracts and conclusions published in Microfilm Abstracts. (1954.)

A KINETIC STUDY OF THE CATALYTIC LIQUID PHASE HYDROGENATION OF CYCLOHEXANE.* **Don B. Schiewetz,** University of Cincinnati. Prof. Robert H. Price, 150 pp. Copies available from university chemistry library. (August, 1954.)

A KINETIC STUDY OF THE STEAM-CARBON REACTION BY THE FALLING PARTICLE METHOD.* **James M. Dotson,** West Virginia University. Prof. W. A. Koehler, 125 pp. One copy available from university library. (May, 1954.)

KINETICS OF THE CATALYTIC HYDROGENATION OF LIGHT OLEFINS.* **James R. Fair, Jr.,** University of Texas. Prof. H. F. Rase, 150 pp. One copy available from university library. (October, 1954.)

KINETICS OF THE CATALYTIC OXIDATION OF SULFUR DIOXIDE ON A VANADIA CATALYST IN FLUID AND CONFINED STATES.* **Max Goldman,** Carnegie Institute of Technology. Prof. Robt. B. Beckmann, 171 pp. Copies available from Carnegie. (March, 1954.)

KINETICS OF CYCLOÖCTATETRENE SYNTHESIS FROM ACETYLENE. Robert H. Haas, Case Institute of Technology. Prof. T. J. Walsh, 135 pp. Microfilm copy available from library of Case $1.50. (June, 1954.)

KINETICS OF THE HOMOGENEOUS LIQUID-PHASE REACTION BETWEEN PROPYLENE OXIDE AND METHYL ALCOHOL CATALYZED BY SODIUM HYDROXIDE.* **Hector A. Pecorini,** University of Michigan. Prof. Julius T. Banchero, 191 pp. One copy available from general library. Positive microfilm 1¼ cts. a page. Abstracts and Conclusions published in Microfilm Abstracts. (1953.)

KINETICS IN PROCESSING ASPHALTIC RESIDUES. John D. Holmgren, University of Florida. Prof. H. E. Schweyer, 116 pp. Copy available from engineering library of university. Photostat 25 cts. a page + $1.; microfilm $20. (June, 1954.)

KINETICS OF THE REDUCTION OF TUNGSTEN OXIDE WITH HYDROGEN.* **Robert R. Reeves,** Rensselaer Polytechnic Institute. Prof. Joel O. Hougen, 75 pp. Copy available from Rensselaer library. (June, 1954.)

OXIDATION OF AROMATIC HYDROCARBONS IN FLUIDIZED CATALYST SYSTEMS.* **Hari Krishan Pargal,** University of Colorado. Prof. Paul L. Barrick, 82 pp. One copy available from university library. (1954.)

REACTION KINETICS IN FLUIDIZED BEDS.* **Chung Yu Shen,** University of Illinois. Prof. H. F. Johnstone, 107 pp. Copies available from university library. Microfilm from University Microfilms, Ann Arbor, ¼ cts. a page. (July, 1954.)

ROLE OF PROPYLENE IN THE PARTIAL OXIDATION OF PROPANE.* **Robert C. Reid,** Massachusettts Institute of Technology. Prof. C. N. Satterfield, 327 pp. Photostats and microfilm available from Hayden Library, M.I.T. (February, 1954.)

STUDY OF CARBON-STEAM SYSTEMS. **Shao E. Tung,** Massachusetts Institute of Technology. Profs. W. K. Lewis and E. R. Gilliland, 422 pp. Photostats and microfilm available from Hayden Library, M.I.T. (February, 1954.)

A STUDY OF THE KINETICS OF IRON OXIDE REDUCTION.* **Wallis A. Lloyd,** University of Minnesota. Prof. N. R. Amundson, 145 pp. (July, 1954)

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Mass Transfer

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MASS TRANSFER IN TURBULENT LIQUID FILMS. **Harold M. Belkin,** Carnegie Institute of Technology. Prof. Carl C. Monrad, 123 pp. (December, 1953.)

SEPARATION OF LIQUIDS BY THERMAL DIFFUSION. **John E. Powers,** University of California. Prof. Charles R. Wilke, 162 pp. One copy available from university library. Photostat 45 cts. a page. Record print 20 cts. per page. (August, 1954.)

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Metallurgy

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PARTIAL PHASE DIAGRAM OF TITANIUM-NITROGEN, TITANIUM-OXYGEN AND TITANIUM-BORON. **Adolph E. Palty,** New York University. Prof. John P. Nielsen, 198 pp. One copy available from university library. Paper published. (April, 1954.)

Mixing

DESIGN, OPERATION AND PERFORMANCE OF BENCH-SCALE REACTORS.* **John R. Snyder,** University of Pennsylvania. Profs. P. Frank Hagerty and M. C. Molstad, 119 pp. Copies available from university library after June, 1956. Photostat $41.65; microfilm $4.50. (June, 1954.)

Phase Equilibria

PHASE EQUILIBRIUM AT ELEVATED PRESSURES IN TERNARY SYSTEMS OF ETHYLENE AND WATER WITH ORGANIC LIQUIDS.* **Jacques J. Weinstock,** Princeton University. Prof. Joseph C. Elgin, 86 pp. Two copies available from Firestone Library of university. (April, 1954.)

THE SOLUBILITY OF HYDROGEN IN NONPOLAR SOLVENTS. **Marshall W. Cook,** University of California. Prof. Donald N. Hanson. One copy available from university library. Photostat 45 cts. a page; record print 20 cts. a page. (January, 1954.)

VAPOR-LIQUID EQUILIBRIA OF METHYL CAPROATE-METHYL CAPRYLATE MIXTURES AND THE APPLICATION OF THERMODYNAMICS TO VAPOR-LIQUID EQUILIBRIUM DATA.* **William W. Sanders,** Pennsylvania State University. Prof. Arthur Rose, 124 pp. Copies available from university library. (July, 1954.)

Thermodynamics

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CALORIMETRIC MEASUREMENTS ON HIGH PURITY IRON AND EUTECTOID STEELS.* **M. L. Picklesimer,** University of Tennessee. Prof. E. E. Stansbury, 105 pp. Copy available from university library. (August, 1954.)

A DETAILED STUDY IN THE APPLICATION OF THE BENEDICT EQUATION TO ONE-COMPONENT SYSTEMS.* **John B. Opfell,** California Institute of Technology. Prof. B. H. Sage, 148 pp. (June, 1954.)

THE EFFECT OF PRESSURE ON MISCIBILITY. **Elliott P. Doane,** University of Illinois. Prof. H. G. Drickamer, 134 pp. Two copies available from university library. Microfilm available from University Microfilms, Ann Arbor, 1¼ cts. a page. (October, 1954.)

PHASE EQUILIBRIUM IN THE 1-BUTANE—WATER SYSTEM AND CORRELATION OF HYDROCARBON—WATER SOLUBILITY DATA.* **Thomas W. Leland, Jr.,** University of Texas. Profs. K. A. Kobe and J. J. McKetta, 126 pp. Copy available from university library. (June, 1954.)

A THERMODYNAMIC AND SPECTROSCOPIC STUDY OF ETHYLENE OXIDE. **Charles W. Arnold,** University of Texas. Prof. K. A. Kobe, 130 pp. Copy available from university library. (June, 1954.)

Miscellaneous

BONDING OF BUTYL RUBBER TO 70/30 BRASS.* **Tung Hung Ling,** Case Institute of Technology. Prof. George W. Blum, 105 pp. Microfilm available from Case library, $1.50. (June, 1954.)

PHYSICAL CHEMISTRY OF FIRE-FIGHTING FOAM AND FOAMING AGENTS.* **Richard Chang,** Syracuse University. Prof. C. S. Grove, Jr., 194 pp. One copy available through Interlibrary loan. (May, 1954.)

I. RADIAL DIFFUSION IN A TURBULENT AIR STREAM. II-a. ABSORPTION OF LIGHT BY THE SYSTEM NITRIC ACID-NITROGEN DIOXIDE-WATER. II-b. IONIZATION IN SOLUTIONS OF NITROGEN DIOXIDE IN NITRIC ACID FROM OPTICAL ABSORBANCE MEASUREMENTS. III. KINETICS OF THE DECOMPOSITION OF SODIUM DITHIONITE. IV. THE DETERMINATION OF CHROMIUM BY OXIDATION IN THE PRESENCE OF SILVER NITRATE.* **Scott Lynn,** California Institute of Technology. Profs. B. H. Sage and W. H. Corcoran, 198 pp. Copy available from library of California Institute. (June, 1954.)

Fig. 1. Single product grass-roots chemical plant.

Fig. 2. Large multiproduct chemical plant.

estimating costs of process plant auxiliaries

H. Carl Bauman | Chemical Construction Corporation, New York

Determinants of chemical plant costs are so numerous and complex that accurate correlation of them would seem a formidable task. This is especially true in the case of auxiliaries, where it is necessary to consider such diverse factors as geographical location, size and type of plant, cost and efficiency of labor and process, availability of fuel and water, personnel requirements, and proximity to equipment suppliers. However, careful evaluation of all the considerations involved reveals certain definite relationships which are set forth below. Data are presented on a unit basis in somewhat idealized form to indicate relative magnitudes and variations within the limits of rough estimating accuracy. For purposes of analysis all installed costs have been referred to current prices and labor efficiency typical of the industrial area of the southwest United States, although this paper covers costs in chemical plants all over the United States and Canada.

The commonly accepted definition for chemical plant auxiliaries includes all structures, equipment, and services which do not enter directly into the chemical process. Within this broad category there are two major classification, namely utilities and service facilities.

A. Utilities

1. Steam
2. Electricity
3. Gas
4. Water (cooling towers and pumping stations)
5. Water treatment
6. Refrigeration
7. Plant air

(Costs of utilities are considered from their sources within plant limits to the limits of the chemical process served.)

B. Service Facilities

1. Auxiliary buildings such as office, medical, personnel; changehouses, guardhouses, warehouses and maintenance shops
2. Roads and walks
3. Railroads
4. Fire protection systems
5. Communication systems
6. Sanitary and industrial waste disposal systems

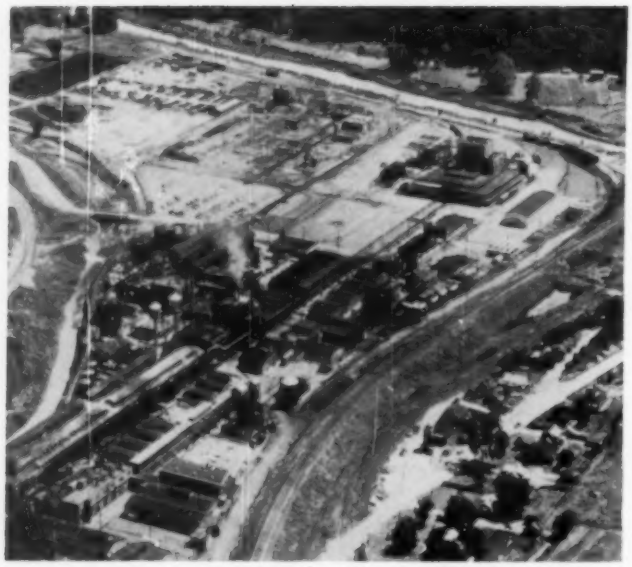


Fig. 3. A large diversified-product chemical plant.

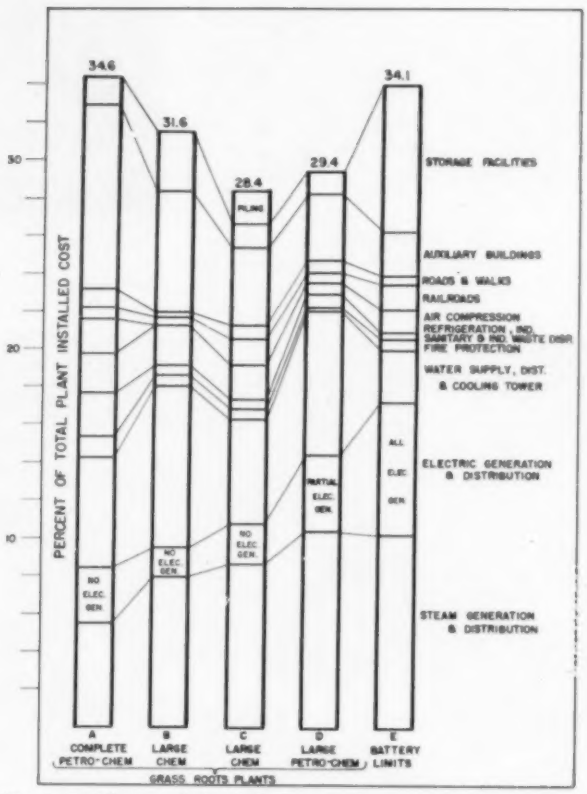


Fig. 4. Distribution of chemical plant auxiliaries in % of total plant installed cost for five large chemical projects.

7. Storage facilities for end product, water, and fuel not directly connected with the process
8. Plant service vehicles, loading and weighing devices

Auxiliaries

The cost of chemical plant auxiliaries as previously defined ranges from 20% to 40% of the total installed plant selling price. For a single product small plant employing fewer than 50 employees per shift, the cost is likely to be close to 20%, increasing to 40% for a large, multiprocess grass-roots * plant (Figures 1-3).

A study was made of the costs of auxiliaries in four of these grass-roots chemical plants, three of which were located in southwest United States and one in northwest Canada, each producing more than two end products. Costs for a fifth large chemical plant designed as a battery limit extension ** to an existing plant were also investigated (see Figure 4).

Installed costs for each of the first four plants exceeded $20,000,000. The battery limit plant is estimated at somewhat less than $10,000,000.

* A complete plant—everything from the ground up—erected on a virgin site.

** Extension to an existing plant; a unit within a complex.

Chemical plant auxiliaries for the four grass-roots plants varied from 28.4% to 34.6% of their respective total plant costs. The cost of the battery limit plant auxiliaries was 34.1% of the total. This unusually high figure is due to the extraordinarily high percentage of storage facilities required by the client and the inclusion in the project of a complete outdoor steam and electric generating station.

Reduction of the storage facilities to the more reasonable value of approximately 4% and subtraction of the electric-generation facilities bring the cost for auxiliaries down to approximately 25% of the total plant cost. This is more in line with the norm for a large battery limit addition.

In these installations steam generation and distribution, water supply and distribution, and auxiliary buildings account for more than half but less than two thirds of the total auxiliary cost for each plant. With due allowance for unusual variations, there is reasonably good correlation between auxiliary costs in these plants.

Studies have been made of the variations in cost of auxiliaries for plants such as sulfuric acid, nitric acid, ammonia, and certain pharmaceutical process facilities. Because of the many variables involved in site, labor and process modification, the degree of correlation even among similar plants was only slightly higher than the correlation among all types of plants. This is due to the fact that though costs of utilities depend largely on the specific process and its requirements, costs for other auxiliaries such as buildings, roads, sanitation, and communications are determined by the size of the plant and the number of employees.

Another factor that tends to upset close correlation of costs among plants is the inclusion or omission of certain auxiliaries as refrigeration, air compression, storage, electric generation, and water installations.

A study of costs of fifty chemical plants of various processes resulted in the preparation of the data shown in Figure 5 and Table 1, which indicate the range of the variation in percentage of total installed plant cost of chemical plant auxiliaries.

The cost range appears to vary most widely in chemical plant auxiliary buildings, as shown in Table 2 and Figure 6. This is logical when one considers the many types and functions of auxiliary buildings in addition to the variations in type and quality of construction materials and methods. For example, a basic chemical plant such as an ammonia unit would be expected to have a minimum

at 600 lb./sq.in. gauge and 750° F. T.T. median costs vary from $300/kw. for a

Fig. 5. Chart showing range of variation in % of total installed plant cost of chemical plant auxiliaries.

Fig. 6. Range of unit erected equipped costs for typical chemical plant auxiliary buildings.

practical type of office structure, and a modern pharmaceutical plant would be expected to have the relatively more expensive steel-, brick-, and plaster-wall type of office building construction.

Table 1.—Variation in % of Total Installed Plant Cost

Chemical Plant Auxiliaries

Auxiliary	Range %	Median %
Auxiliary Buildings	3-10	6.5
Steam Generation	4-10	7.0
Electric Generation	3-7.5	5.3
Water Cooling	2.5-6.5	4.5
Water Distribution	1.5-3.5	2.5
Water Pumping	1.2-2.4	1.8
Storage Facilities	1.5-5.5	3.5
Electric Distribution	1.5-2.5	2.0
Refrigeration	.3-2.1	1.2
Air Compression	.1-1.9	1.0
Steam Distribution	.5-2.5	1.5
Gas Distribution	.2- .4	.3
Fire Protection	.3-1.2	.75
Sanitary Waste Disp.	.3- .7	.5
Industrial Waste Disp.	.4-1.8	1.1
Boiler Feed Water Treatment	.2-1.5	.85
Railroads	.3-1	.65
Roads and Walks	.2-1.2	.7
Communications	.1- .3	.2
Yard and Fence Lighting	1- .4	.25

Steam

Steam-generating facilities apparently represent the second largest investment for chemical plant auxiliary equipment. Here, too, variations in size of installation, location indoors or outdoors, kind of fuel fired, pressure and temperature levels, and the type of process served have an important bearing on the actual cost as well as the cost relative to the other auxiliaries.

Figure 7 shows installed unit costs of chemical plant steam-generating facilities as functions of some of these variables. The curves are idealized trends plotted from data obtained from outdoor and indoor installations operating at different ranges of pressure and temperatures.

The first two are so called "package-boiler" installations which may be purchased as assembled, piped, and wired units ready to be erected on the client's foundations. These may be purchased in units up to 35,000 lb./hr. of steam capacity. Capacities on this chart in excess of 35,000 lb./hr. represent installations of more than one unit. Installation costs for 150 lb./sq.in. gauge saturated package boilers vary from $6.00 to $4.50/lb. for installations to 70,000 lb./hr.

The cost for 300 lb./sq.in. gauge-750° F. T.T. package boiler installations ranges from approximately $7.80 to $5.10/lb. of steam for outdoor installations. Buildings increase the cost from 15% to 20%. The cost analysis is based on a 400-600 lb./sq.in. gauge and 600-750° F. T.T. range because of the trend

Table 2.—Range of Unit Erected Equipped Costs for Typical Chemical Plant Auxiliary Buildings

Auxiliary Building	Cost-Range dollars/sq.ft.		Median Cost dollars/sq.ft.
Cafeteria Bldgs.	25	35	30.00
Laboratory and Medical Bldgs.	22.50	32.50	27.50
Personnel Office Bldg.	20	27	23.50
General Office & Admin. Bldgs.	12.50	22.50	17.50
Change Houses	16	20	18.00
Shop Buildings (Less Equip.)	11	14	12.50
Warehouses	9	17	13.00

including foundations and 440 v. switchgear, costs $40.00/kva.

River intake and filtering installations range from $15.00 to $5.00/gal./min. of

ment costs will vary widely with quality of water, per cent of dissolved solids,

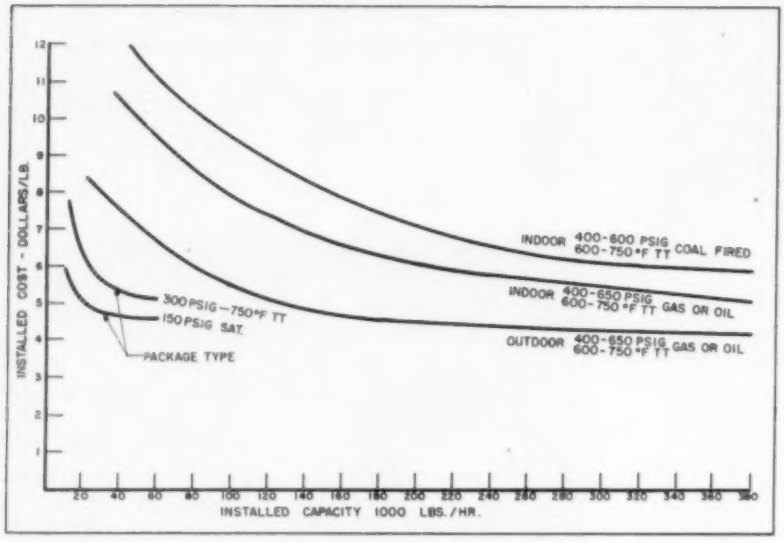


Fig. 7. Idealized trend curves showing estimated unit installed costs of indicated steam generator facilities.

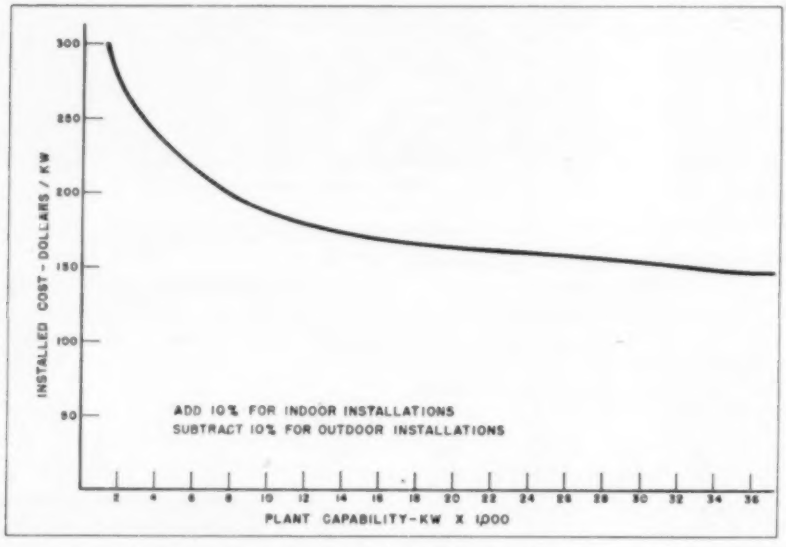


Fig. 8. Idealized median unit cost vs. capability kw. for electric generation plants based on 600 lb./sq.in. gauge—750° F. TT.

to higher temperatures and pressures for generating facilities in modern chemical installations. This development is particularly evident in plants where back pressure turbines can be used as drives and as reducing valves for lower pressure process steam.

The idealized cost trend curves reflect the higher unit costs for indoor vs. outdoor installations and the higher cost of coal-fired vs. gas- and/or oil-fired plants.

Depending on the capacity the cost of a typical coal-fired installation varies from \$12.00/lb. for a 40,000 lb./hr. boiler to \$6.30/lb. for a 300,000 lb./hr. plant. The equivalent gas- or oil-fired plant varies from \$10.60/lb. to \$5.70/lb. Cost of an outdoor gas or oil installation for the same capacity range varies from \$7.50/lb. to \$4.50/lb. of steam. It must be emphasized that these are idealized trend curves showing relative magnitudes for rough estimating. They can not be used to price specific installations without a careful analysis of all factors involved.

Electricity

In most sections of the United States now, there is an adequate supply of reliable electricity furnished by the public utilities. Consequently, there has been a marked decrease in the number of chemical installations which include private electric-generating facilities. However, in some cases, electric generation is still economically feasible or necessary. For generation plants operating at 600 lb./sq.in. gauge and 750° F. T.T. median costs vary from \$300/kw. for a 2000-kw. installation to \$150/kw. for a 36,000-kw. plant. (Figure 8). Costs will be somewhat higher for installations at higher pressures and temperatures. However, few private generating plants operate at higher throttle conditions than shown above.

Though few chemical plants generate their own electricity all have electric-distribution systems starting at their own generating plant's terminals or at the power company's service point on the plant's property. Many factors such as lightning hazards and corrosive conditions influence the choice of an electric-distribution system resulting in the use of various types of underground and overhead systems. The cost of electric distribution includes main substations, distribution substations, feeders, switches, and appurtenances. Overhead distribution systems are one third to one half as expensive as underground systems.

With 100-ft. spans, overhead systems of insulated aerial cable supported on messengers strung between wooden poles cost from \$9.00 to \$12.00/ft. of pole line installed, depending on size of conductor ranging from No. 6 American Wire Gauge to 500 M cir. mills.

For this range an equivalent system of bare conductors on wood poles, including lightning arresters on alternate spans, costs from \$4.00 to \$8.00/installed foot of overhead distribution.

Underground systems using fiber duct banks encased in concrete, manholes, substations, and cables range from \$30.00 to \$60.00/lin. ft. of distribution depending on the number of ducts in the bank, length of system, voltage and capacity of system, soil and temperature conditions.

The cost of underground distribution in fiber concrete encased ducts including manholes, less substations, ranges from \$20.00 to \$35.00/lin. ft. of duct bank.

Some plants have used direct burial cable underground systems. Costs for such installations, including cable and substations, range from \$15.00 to \$35.00/lin. ft. Cost for this type of distribution, less substations, ranges from \$10.00 to \$20.00/lin. ft.

Substations, depending on capacity, voltage, and type cost from \$15.00 to \$40.00/kva. installed. Some typical examples follow.

A 3000 kva., 25,000/2500 v. outdoor substation, including foundations, steel structure, and appurtenances, transformer and 2-2300 v. switchgear was installed for \$17.00/kva. complete.

A 1000 kva., 25,000/400 v. unit-type substation with foundations and metal clad switchgear costs \$30.00/kva.

A 500 kva., 2500/400 v. unit-type substation,

\$.80/bbl. for an 80,000-bbl. installation

including foundations and 440 v. switchgear, costs $40.00/kva.

Water

Water systems rank third highest in cost of chemical plant auxiliaries, with cooling towers representing the largest portion of the plant investment in water supply and distribution facilities. As might be expected, the higher the temperature range the more costly the tower installation (see Figure 9). For example, for an 85° F. wet bulb, a 30° F. terminal difference, and a 5° F. approach the installation tower cost varies from $23.00/gal. for a 2000 gal./min. tower to $11.00/gal. for a 28,000 gal./min. installation.

For a 75° F. wet bulb, 15° F. terminal difference, and a 10° F. approach the equivalent costs are $12.00/gal. and $5.00/gal.

River intake and filtering installations range from $15.00 to $5.00/gal./min. of installed capacity in systems ranging from 500 to 100,000 gal./min.

The cost for boiler feed water-treating equipment has been previously included in the costs for complete steam-generating facilities. Cost of zeolite ion-exchange systems varies from $600/gal. for 50 gal./min. of installed capacity to $500/gal. for a 300-gal./min. installation.

The hot process lime systems vary from about $350/gal. for a 100-gal./min. system to $150/gal. for a 2000 gal./min. system. (See Figure 10.) It is reiterated here that these are idealized costs and must be used with a full realization of all factors involved in selection and specification of water-treatment systems. Costs shown are somewhat pessimistic, but water-treatment costs will vary widely with quality of water, per cent of dissolved solids, and total hardness.

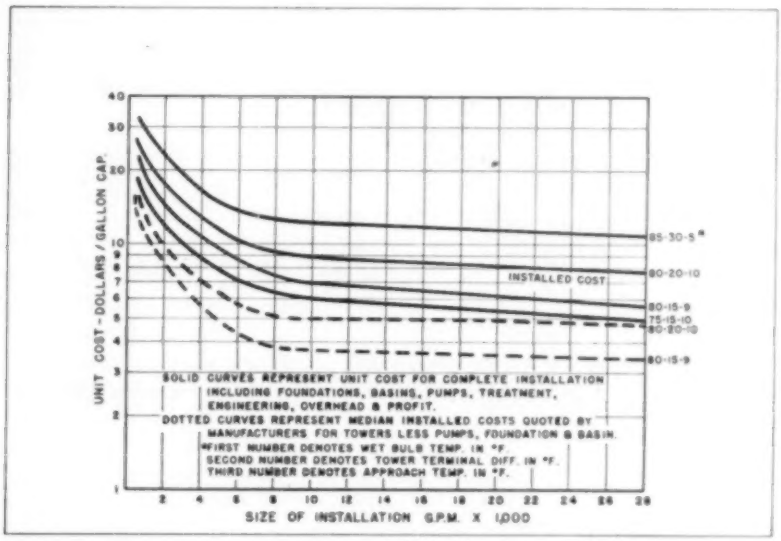


Fig. 9. Median unit costs for estimating industrial cooling tower installation costs.

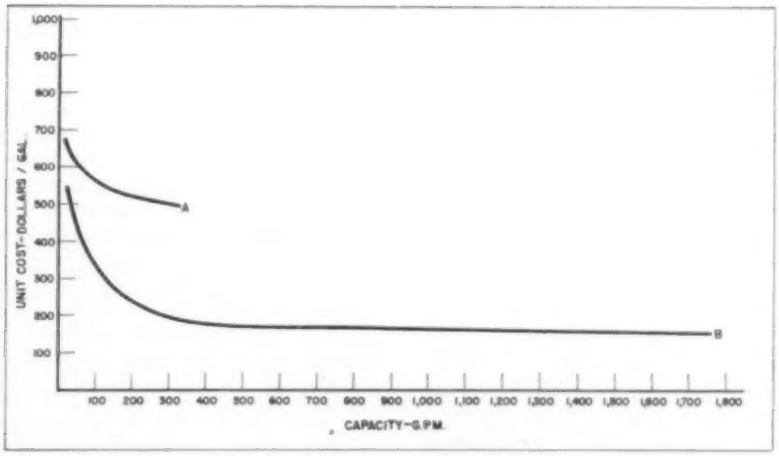


Fig. 10. Idealized unit installed costs for water treatment systems (a) zeolite (b) hot process.

Refrigeration

Refrigeration is an increasingly important auxiliary required for many new processes. Figure 11 shows an idealized plot of the installed unit costs for refrigeration systems vs. capacity in tons of refrigeration. The curves are drawn for one specific suction and discharge condition (25 lb./sq.in. gauge and 200 lb./sq.in. gauge respectively) and are for direct-expansion systems. Curve A represents unit installed costs for reciprocating ammonia compressors and shows a variation of from $400/ton for a 10-ton system to $275/ton for a 500-ton system. Curve B is for centrifugal ammonia and/or Freon 12 compression system and shows a variation of from $400/ton for a 100-ton system to $200/ton for a 2000-ton system.

It is interesting to note that at approximately 500 tons of capacity and above, it becomes more economical to consider centrifugal-compressor refrigeration systems.

A family of curves can be drawn to show the cost of refrigeration systems for other suction and discharge conditions. As suction pressure is decreased, cost will increase sometimes as much as 25% for equivalent capacity ratings, assuming the same discharge pressure.

Storage

Storage facilities for chemical plants take many forms. Liquids are stored in tanks and spheres, gases in pressure tanks and gas holders, bulk solids in bins, outdoor and indoor piles.

Figure 12 shows the idealized relationship between unit-installed cost of sphere storage facilities and capacity in barrels (42 U.S. gal./bbl.). The increase in cost as operating pressure increases is evident.

The installed cost exclusive of pumping facilities of 75 lb./sq.in. gauge spheres varies from $13.00/bbl. for a 2000-bbl. sphere to $7.20/bbl. for a 16,000-bbl. sphere. For the 30-lb./sq.in. gauge sphere installed costs vary from $6.20/bbl. for a 6000-bbl. sphere to $4.50/bbl. for a 24,000-bbl. installation.

Elevated storage tanks vary in cost from $.28/gal. of capacity for a 50,000-gal. tank to $0.15/gal. for capacities of 500,000 gal. and more. Total installed costs for horizontal storage tanks vary from $8.00/bbl. for a 500-bbl. tank to

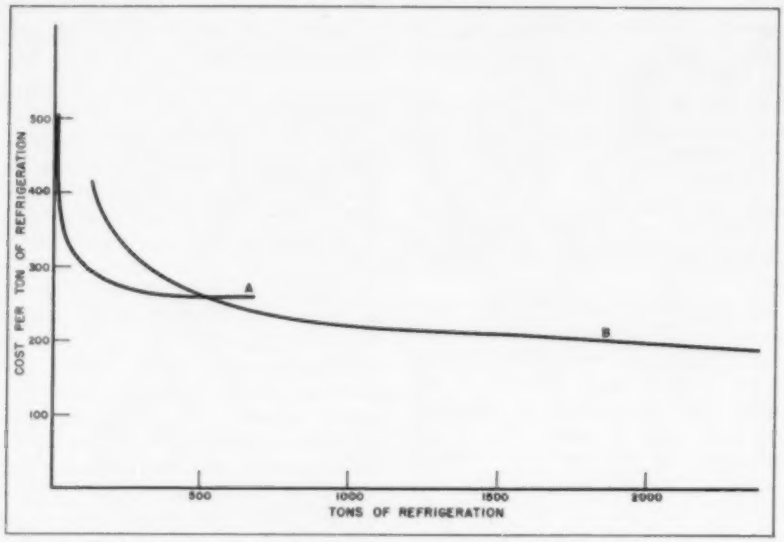


Fig. 11. Idealized installed unit costs for refrigeration based on 25 lb./sq.in. gauge suction, 200 lb./sq.in. gauge discharge, direct expansion systems. (A) reciprocating machines (NH_3) (B) centrifugal machines (F_{12}) & $(NH)_3$.

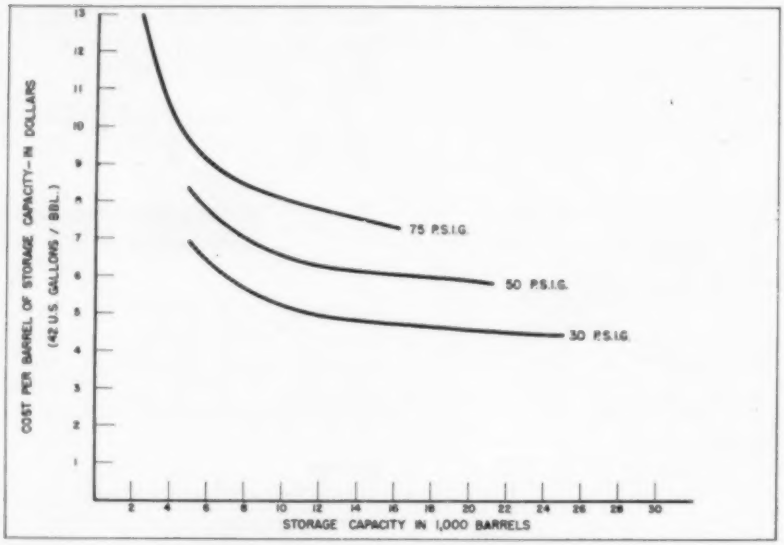


Fig. 12. Unit installed cost of storage facilities—spheres.

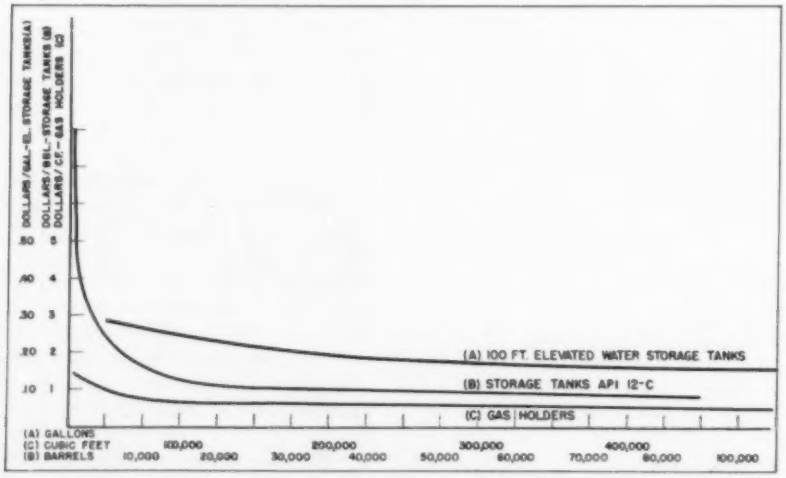


Fig. 13. Unit erected costs for storage facilities. (A) elevated water storage tanks, (B) product storage tanks, (C) gas holders.

$.80/bbl. for an 80,000-bbl. installation (Figure 13). The unit costs for vessels of these types, as shown by the curves, tend to flatten out quickly as sizes increase from the minimum, and they remain substantially constant over a wide range of sizes. Gas-holder unit-installed costs vary from $2.10/cu.ft. of capacity for 10,000-cu.ft. tanks to $.45/cu.ft. of capacity for 500,000-cu.ft. capacities and above.

Roads and Walks

Costs of roads and walks for chemical plants vary with type and thickness of cover. Some typical unit costs for roads are:

Gravel and Asphalt	$2.50 to $3.00/sq.yd.
Concrete with 6-in. base	3.25 to 3.75/sq.yd.
Concrete with 8-in. base	4.50 to 5.25/sq.yd.

Railroads

Installed costs for railroads including switches and frogs may be estimated as follows:

Linear footage	Per linear foot
500 to 1,000	$13.50
1,000 to 3,000	13.00
3,000 to 10,000	12.50

Above 10,000 approaches $11.00/lin. ft.

Waste Disposal and Fire Protection

Some other unit costs which prove useful for chemical plant estimating are shown here.

Sanitary sewage systems may be installed for $150-200/employee.

Fire alarm installations, with overhead wiring systems, cost from $80.00 to $100.00/station and paging systems may be estimated at $60.00 to $80.00/call.

The validity of estimating costs on a unit basis depends on the thoroughness, care, and intelligence with which suitable data are compiled and correlated. Correlations with high confidence ratios can be achieved without extensive sampling provided the data are analyzed accurately to eliminate most of the variables. The effectiveness of the method depends on a constant awareness of changing equipment, labor, and material prices.

Presented at a New York Local Section meeting, October 13, 1954.

THE CHEMICAL ENGINEERS CAME TO NEW YORK

The 1954 Annual Meeting of the Institute in New York City topped all previous attendance records. More important, however, is in spite of the size of the attendance—about 2,800—the meeting managed fairly well to retain the informality and the good fellowship which has come to be an outstanding quality of Institute meetings.

This Annual Meeting will go down in history as marking the end of a major era in Institute affairs—and, of course, the beginning of a new era. The end of one era is marked by the retirement of S. L. Tyler, Secretary and Executive Secretary for seventeen years. The new era is being ushered in under the stewardship of F. J. Van Antwerpen, newly elected Secretary, who Council had appointed earlier in the year to the post of Executive Secretary.

At the gala Awards Banquet, Tyler was presented with a watch, a book containing written expressions by previous officers of the Institute relating to past experiences, and a check representing a gift from the Local Sections of the Institute.

Barnett F. Dodge, professor and head of the chemical engineering department at Yale University, took the oath of office as the President of the Institute. In his remarks, Dr. Dodge termed his election "the highest honor I have ever received." In speaking of the responsibility entailed, he said, "I know I can count on the help and support of the membership to make the coming year one of substantial progress in furthering the objectives of the Institute."

Plant trip scene; one of the groups touring California Oil Co. refinery.

Getting Ahead

The Sunday afternoon panel forum devoted to "Growing into management—how a professional society can help," was attended by more than 600, of which only a small number indicated by a showing of hands to be local people.

Panel members included W. S. Brackett (Carbide & Carbon, Charleston, W. Va.), Martin Buck (Shell Chemical, N. Y.), R. P. Dinsmore (Goodyear, Akron), L. P. Scoville (Diamond Alkali, Cleveland) and F. J. Van Antwerpen (A.I.Ch.E. secretary-elect, N. Y.).

Moderator was J. A. Hufnagel (Fluor Corp., N. Y. office), who was introduced by Roland Voorhees (Carbide & Carbon), chairman of the A.I.Ch.E. Committee of Professional Development. President C. G. Kirkbride (Houdry Process Co.) opened the meeting.

(*Continued on page* 38)

TECHNICAL PAPERS TO BE REVIEWED IN FEBRUARY & MARCH

A review of the technical papers presented at the New York meeting will begin in the February issue of C.E.P., and may continue on into the March issue. This is a new policy of the magazine—to spread the meetings reports over several issues in order to do them better justice, and at the same time not crowd other important material which should be published immediately following major meetings. Consequently, it is our plan to have a meeting report in each issue of C.E.P.—*Editor*.

Committee meeting.

This Scrubber handles Hydrochloric Acid and Chlorinated Solvents at High Temperatures

. . . . . Materials and Construction by EL CHEM

• The Tail Gas Scrubber shown at right is one of EL CHEM's recent installations in the chemical processing industries. This type of construction, planned, engineered and installed by EL CHEM, is used in plants producing organic chemicals.

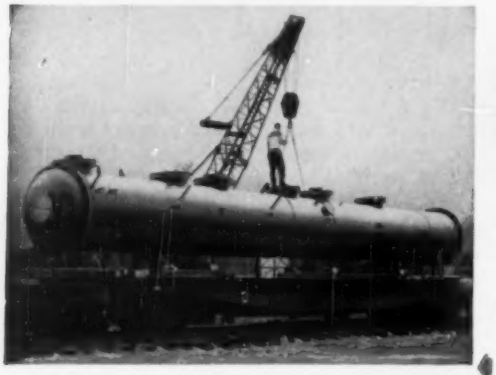
• It resists acids, *all alkalis* and most organic liquids. It features also high heat resistance.

• *All materials of construction* (listed below sketch) *are manufactured by* EL CHEM. Among them is LECITE, a recent development in Furfuryl Alcohol resin cement.

• As a corrosion-proof bonding agent, LECITE combines the desirable properties of the phenolics, without their drawbacks. It serves also as an impervious liner, when reinforced with glass cloth or metal mesh, as mortar for corrosion-proof brick lining and as an impervious membrane between brick or tile floor and the concrete sub-base.

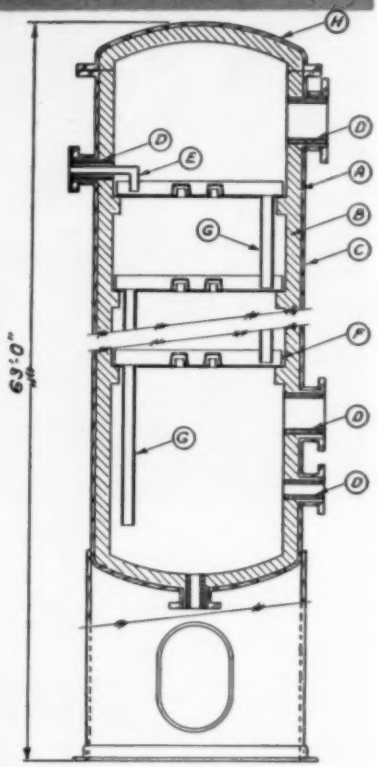
• LECITE is used in the construction of acid-proof floors, chemical process equipment, such as scrubbers, reactors, storage tanks, filters, alkylators, neutralizing tanks, stacks and fume ducts.

• LECITE has been used successfully for many years in plants producing chemicals, dyes, Viscose, nylon, textiles, synthetic resins, petroleum products, steel, copper and many others.



DURO-WARE bubble cap tray (f) in drawing at right.

Assembled at our Emmaus plant, shipped out by rail and installed by us at destination.



(a) EL CHEM combination membrane
(b) One layer acid-proof brick, joined with LECITE acid-, alkali- and solvent-proof resin cement
(c) Welded steel shell
(d) Porcelain sleeve
(e) DURO-WARE inlet pipe
(f) DURO-WARE bubble cap tray (see picture at left)
(g) DURO-WARE downcomer
(h) Brick-lined removable dished head

EL CHEM renders a complete, all-inclusive service: materials, plans, engineering and installation. Our engineers will survey your corrosion problem, make recommendations and prepare plans and estimates — without obligation. At your command here is the benefit of more than four decades of experience in solving about every kind of problem in industrial corrosion. *Write for technical literature.*

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			San Francisco, Calif.	HUmboldt	3-1976			

lead reference sheet (part I)

Kempton H. Roll Technical Director, Lead Industries Association, New York

Grades of Lead:

Chemical lead, acid lead, and copper lead are the A.S.T.M. grades of lead most commonly used for corrosion resistant chemical construction. These three grades are distinct from antimonial lead (hard lead) and tellurium lead, used in chemical construction.

Antimonial Lead:

Is ordinary lead to which has been added up to 12% antimony. Though this hardens and improves the mechanical properties, antimony lowers the melting point and does not enhance corrosion characteristics. At temperatures below 200° F., 6% antimonial lead has more abrasion resistance than chemical lead. At room temperature it has twice the hardness and tensile properties, but at about 200° F. the mechanical strength of antimonial lead is no better than chemical lead and above this temperature chemical lead actually possesses equal or better mechanical characteristics.

Tellurium Lead:

Is chemical lead to which has been added approximately 0.04% tellurium to improve resistance to fatigue due to vibration. Tellurium retards grain growth and allows lead to work harden or strengthen itself under strain.

Applications:

Lead has long been widely used in the construction and protection of equipment for the production, transmission, storage, and use of corrosive chemicals. It is especially useful with all concentrations of sulfuric acid, sulfurous acid, chromic acid, phosphoric acid, and salts of these acids.

Forms:

In chemical construction lead is used chiefly in the form of rolled sheet, pipe or other extrusions, castings, or as a lead cladding on steel or copper. Either existing or specially constructed vessels of concrete, wood, or steel can be readily lined with sheet lead to make them suitable for handling corrosives. A thick layer of lead can be bonded to steel or copper as a cladding to combine the corrosion resistance of lead with the working strength of the base metal.

Valves and Castings:

As lead has a low melting point in combination with high density and corrosion resistance, it has had extensive use, particularly antimonial lead (4 to 6% Sb), in castings. Cast hard lead valves are standard items for handling liquid corrosives and include gate, check, diaphragm, standard Y, and split Y body styles. In addition to solid hard lead valves, lead-lined cast-iron and lead-lined cast-steel valves are available commercially for use at higher pressures and temperatures. Lead castings are used in the chemical industry in the form of reaction vessels, evaporators, etc., usually made from 4% hard lead.

Mechanical and Physical Properties:

(All data apply to chemical lead.)

Tensile strength	2300 to 2800 lb./sq.in.
Elongation	42 to 57%
Brinell hardness	4.5 to 6.0
Density, rolled, g./cc.	11.35 to 11.37
Melting point	618° F.
Mean specific heat (B.t.u./(lb./° F.) 60° F. to 618° F.	0.032
Thermal expansion ($\times 10^{-6}$ in./in./° F.) 32° F. to 212° F.	16.3
Thermal conductivity (cal./(sq.cm.)(cm.) (° C.)/sec.) 68 ° F.	0.082
Creep ($\times 10^{-5}$, %/hr. at 200 lb./sq.in.) 68° F.	0.4
Electrical Resistivity (micro ohms/cc.) 68° F.	20.648

Heat Treatment:

Lead is a self-annealing metal, and therefore never needs heat treatment.

Weldability:

Easily joined in the shop or field by fusion welding, known as lead "burning." Method uses no materials other than lead and thus insures that no metal less resistant than lead will be exposed to the corrosive. Eliminates the possibility of galvanic action between dissimilar metals. Should repairs be necessary, they are easily effected in the field.

Thickness:

Thickness of sheet-lead linings depends largely on the degree of corrosive attack or erosion anticipated. Rarely is sheet lead lighter than 8 lb. or ⅛ in. thick used in chemical equipment, thicknesses usually ranging between 10- and 20-lb. (5/32 in. and ¼ in.) Frequently different thicknesses are used for different parts of equipment.

Type of Construction:

Lead sheet supported either in (1) a framework of steel or wood or (2) as a lining in a steel, concrete, or wooden vessel, are the two principal types of sheet-lead construction. They are generally termed (1) cage construction, and (2) lead-lined construction. In the latter, strip or spot bonding or lead-covered steel strapping are usually used to support the lead.

Operation at high temperature or the handling of corrosive slurries which both corrode and erode most materials of construction has led to the development and practical acceptance of brick and lead linings, i.e., a steel shell lined with lead, with or without a layer of asbestos sheeting, followed by a layer or two of acidproof brick set in suitable acidproof cement.

A lead clad or bonded lead lining, in effect, combines the corrosion resistance of lead with the working strength of steel. Lining consists of a layer of lead bonded to steel plate to form a homogeneous or integral metallic structure which permits operation at higher temperatures and in vacuum.

Lead-pipe cooling coils are commonly used. For heating coils copper pipe is covered usually with a lead cladding although lead pipe alone may be used up to 50-lb. steam pressure. Bonding a layer of lead to copper combines the corrosion resistance of the former with the heat transfer and higher strength of the latter. Steel pipes available with internal lead linings. Corrosive gases conducted usually in ducts fashioned from sheet lead supported in a strap iron framework.

Temperature Limitations:

Chemical lead melts at 618° F. At 270° F. it possesses about half its normal strength. Spreading out the time-temperature cycle in periodic operations substantially improves performance. Bonding lead directly to steel as in lead-clad vessels or to copper as in lead-covered copper coils permits operation at higher temperature ranges. By providing an insulating layer of acidproof brick over the lead, still higher temperatures may be successfully tolerated, 500° F. being not uncommon.

Chemical Composition:

A.S.T.M. Pig Lead Specifications * for Chemical, Acid and Copper Lead

	Chemical Lead	Copper Lead	Acid Lead
Ag, Maximum	0.020	0.002	0.020
Minimum	0.002		
Cu, Maximum	0.080	0.080	0.080
Minimum	0.040	0.040	0.040
As, Sb + Sn, Maximum	0.002	0.002	0.015
Zn, Maximum	0.001	0.001	0.002
Fe, Maximum	0.002	0.002	0.002
Bi, Maximum	0.005	0.025	0.10
Lead, by Dif., Minimum	99.90	99.90	99.85

* A.S.T.M. Standard Designation (B 29-49).

No. 41

panel forum

◄ Roland Voorhees.

▲ J. A. Hufnagel, moderator.

▲ The panel: F. J. Van Antwerpen, Martin Buck, Loren Scoville, W. S. Brackett, R. P. Dinsmore.

NEW YORK STORY

(*Continued from page* 34)

"What is management" was the subject of a few minutes of opening remarks by L. P. Scoville, who reported dictionary definitions and contrasted them with the modern concept which has to do more with democratic leadership.

The pattern of the meeting was based on prepared questions read by young chemical engineers in the audience. In assembling material, moderator Hufnagel quizzed local sections well in advance of the meeting. The many replies were consolidated to forty questions, of which there was time for only about twenty.

Spontaneity and freedom of discussion from the floor were sought by frequent appeals from the moderator to "speak up."

A summation of the questions asked can be divided into two classifications: first, management, and second, the A.I.Ch.E.

Some of the points raised about growing into management approached the problem pessimistically. For example, one question was: "Is it really necessary to grow into management to get some place?" In this case the originator of the question seemed to have been wondering why all the attention is on growing in only this one direction. Another was, "Can't straight engineering work be made sufficiently attractive to prevent engineers from leaving it in order to progress?"

Answers to such questions explored into concept of the definition of management—that it constitutes leadership over other people and the taking of responsibility for determining and executing direction. Growing into management can mean growing out of a primary state of self-interest and into one of greater concern for one's fellows and the facilities that make everyone's jobs possible. It was also pointed out that it is management's primary mission to see that the operation for which it is responsible gains more capital than it pays out—in other words, stays in the black and makes money not only for the employees and officers, but the owners as well, if they should be other persons.

One question drew amusement from the audience until its serious quality was made more apparent by the discussion which followed. This was, "How does one know when he has 'arrived' in management?" The panel defined this as the development of a state of awareness (both on the part of the individual as well as members of his management) that the subject person is showing broader

authors

P. Shu; G. A. Brown; I. Caldas; R. K. Finn; M. F. Lau; C. W. Weil; J. W. Delaplaine; M. R. Smith; R. B. Thompson; C. Berg; N. Morash; C. E. Wicks; H. R. Sheely; H. F. Hopp; J. O. Hinze; R. E. Treyball; L. D. Etherington; C. F. Bonilla; H. L. Shulman; E. W. Grohse; J. Y. Oldshue.

interest and willingness to share responsibility along lines deemed constructive in the light of past management experience and patterns.

What aid is needed in growing into management was discussed at length. Some asked if it should be entirely the individual's own responsibility for training and orienting himself to the broader human and business phases of the operation with which he is associated. Others asked if industrial management couldn't do more in defining goals and providing information, as well as guidance. One questioner asked if the Institute couldn't undertake a program of cooperating with industrial managements in providing training material. It was pointed out that the Lake Placid meeting of the Institute, to be held in September, 1955, will be devoted entirely to management considerations.

Part of the questions asked had to do more with the Institute and professional societies in general. This is attributed to the second of the questions sent to Local Sections by moderator Hufnagel, which reads, "What does the Institute member expect the Institute to be and do, so that it can help him in his early professional growth?"

Basic to the answering of this question, was another: "What is professionalism?" This was related to a state of attitude towards one's job . . . something not attained merely through membership in a society, or the earning of a degree. Instead, it was said to be something based on such simple virtues as honesty, respect for one's fellows, etc.

What the Institute can be doing to elevate the standing of engineers in their communities, was another subject discussed. The concensus was that among other activities, continued cooperation with EJC (Engineers Joint Council) would do more to bring this about than would individual efforts by only one society.

l. to r. G. T. Skaperdas; C. F. Gurnham; B. D. Smith; E. H. Lebeis; H. C. Van Ness.

awards banquet

◄ Barnett F. Dodge receives presidential pin from retiring-president C. G. Kirkbride.

▲ l. to r.—Award winners Grace, Quinn, Bowman, Gilliland.

◄ Tyler receives memento from Kirkbride.

Secretary of Commerce of the U. S., The Honorable Sinclair Weeks. ►

Asked was, "What are the principal benefits one gets from belonging to the A.I.Ch.E.?" Newly elected secretary Van Antwerpen replied that it is getting to know more chemical engineers, that is a major benefit. This enables one to learn what they are doing, how they go about solving their problems, and what developments are taking place in their other fields.

Other questions dealt with: Whether the Institute should make a survey on methods of salary administration and job evaluation (panel thought this would be done better by a professional management survey group); what should be done about unethical recruiting practices which have at times left job-candidates stranded when projects didn't materialize (panel felt the guidance professors are capable of handling this, and that their advice is sometimes overlooked in the light of attractive sounding offers); and how many professional society meetings an industrial firm should send its engineers to (this was regarded as an individual problem with each firm).

Whether or not there is a real shortage of engineers was debated, with a number of younger men indicating their doubts. Panel members spoke of frequent and not too rewarding experiences in trying to hire chemical engineers possessing outstanding qualifications for technical, managerial, sales and other work. The panel concensus was that a shortage of highly qualified and/or experienced men does exist. One member of the audience who owns his own firm pointed out that he has succeeded in inducing a number of very ably qualified chemical engineers to leave straight technical work and enter sales, where their training and experience has proved to be of value. He conjectured that such a shifting, if very widespread, might be contributing to shortages in the technically-qualified category.

authors

▲ l. to r.—C. R. Nelson; R. B. Olney; W. E. Catteral; W. E. Smith; L. Fish; T. K. Sherwood; H. P. Grace; N. F. Murphy; L. B. Anderson; J. L. Hammer; R. B. Beckmann.

◄ Authors' breakfast.

◄ Institute Lecturer Manson Benedict.

▲ Above, l. to r., Ladies' group: Grace Kearns, Mrs. H. I. Wolff, Mrs. K. D. Ashley, Mrs. J. B. Mellecker, Mrs. L. C. Byck, Jr., Mrs. J. A. Hufnagel (vice-chairman); TV—Bob Hope & John Daly.

▲ Frank B. White (vice-chairman of Arrangements Comm.), and Mrs. White (member of Arrangements Comm., and chairman of Ladies Comm.).

▲ F. J. Van Antwerpen (new executive-secretary of A.I.Ch.E.), and Mrs. Van Antwerpen.

▲ B. H. Rosen (Public Relations Comm.), Howard L. Malakoff (general chairman of Arrangements Comm.), Mrs. Malakoff (Ladies' Comm.).

On the Social Side

Promised almost every aid in seeing New York City, the chemical engineers and their wives gave every evidence of taking advantage of a good thing. Most popular events were TV broadcast of "What's My Line," theater parties to matinees of two Broadway hit-shows, and the trips to the UN.

The ladies lounge, maintained primarily as a social headquarters for the distaff side, was seldom without men present—obvious testimony to the drawing power of the program events set up primarily for ladies, but to also include men. Mrs. F. B. White and Mrs. J. A. Hufnagel had a well organized, smoothly functioning hospitality and program operation.

Aside from a rather long wait outdoors prior to being admitted to the studio-theatre, the TV broadcast seemed a pronounced success. The chemical engineer for whom all arrangements had been made to be one of the contestants became ill several days prior to the broadcast, so the audience could not be treated to the spectacle of one of their profession undergoing the guessing contest before the eyes of a network audience. Those unable to attend the convention, who watched the TV broadcast from their homes that night undoubtedly noticed Bennett Cerf's courtesy mention of the presence of chemical engineers. We were delighted to have Bob Hope as the guest challenger (see accompanying picture).

First of the major social events on the program was a crowded success. The "get-together" cocktail party of Sunday evening appeared to be attended by more than 1,000 people. Fortunately, the affairs lasted long enough to permit sufficient circulation for those who kept to their original intention of getting around to say "hello" to a lot of folks.

From the cocktail party, groups wandered down to the Cafe Rouge—the New York Statler's luxurious theater-restaurant, where a buffet-style supper was served through the evening until all were cared for. It was interesting to observe how, in such formal surroundings, Institute members and their wives elected to sit at random at the large tables, making new friends.

The famed Cities Service Quartet, heard regularly over the Cities Service radio program, entertained at both the cocktail party and the buffet supper. Credit and thanks are due Mr. Howard Malakoff, General Chairman, for his consideration in proposing and then making the necessary arrangements for the Quartet's appearance.

Columbia's Bicentennial

Columbia University's Bicentennial Luncheon honored the long history of accomplishments and high standards of this great American educational institution. Present at the head table were leaders of both the University and the Institute. Greetings were expressed by president Kirkbride, president-elect Dodge and others from the Institute. Acknowledgements of appreciation were expressed by Dean Dunning (of the College of Engineering) and others from Columbia.

"The philosopher looks at science" was the subject of a talk given by Professor Ernest Nagel, internationally prominent author and lecturer, who is a permanent staff member at Columbia now temporarily visiting Princeton

Press conference; Carl W. Weil (l.) and Don A. Levinson (member and chairman, respectively, of Public Relations Comm.) consult award lecturer John R. Bowman (center).

Dave H. Jackson (Chairman, Entertainment Comm.) and Mrs. Jackson.

University. Key to the Professor's remarks was the phrase, "Man's right to knowledge and the free use thereof," which is the theme of the Bicentennial.

Professor Nagel made a plea for presentation of scientific conclusions in terms of the intellectual method by which they are established. This calls for making known the various logical considerations that enter into the acceptance or rejection of proposed solutions to problems. It places in the forefront the method rather than the results if the latter is isolated from the method used. Professor Nagel believes that greater effort on the part of scientists to make known these considerations will result in an improved climate of understanding and appreciation on the part of the philosophers. Greater interest in the social consequences of engineers' acts or decisions, though this interest might not in any way affect the acts or decisions, are believed necessary to bring about a closer integration of the scientist and the humanities.

Awards Banquet

Most gala of all gala occasions during the meeting was the Awards Banquet.

As is the custom, the outgoing president (Chalmer G. Kirkbride) conducted the affair up to the final event, which was to administer the oath of office to the incoming president (Barnett F. Dodge). In addition, the ceremony includes transferring the pin worn by the president. This year also saw delivery of the "Great Gavel of the Institute." The St. Louis Section finished, since last year, a tremendous gavel of rosewood, stainless steel and a band of silver inscribed with the names of all Institute Presidents. President Kirkbride acknowledged its receipt and displayed it to the banquet audience.

Norman Morash (Vice-Chairman, Tech. Progr. Comm.) and Ted H. Kelly (Vice-Chairman, Arrangements Comm.).

J. R. Dunning (Columbia Univ.) and C. F. Bonilla (Vice-Chairman, Bicentennial Luncheon Comm.).

Award winners presented at the banquet by Professor R. H. Wilhelm (Princeton Univ.) were: John M. Bowman (Mellon Institute), the Professional Progress Award; E. R. Gilliland (M.I.T.), the William H. Walker Award; H. P. Grace (DuPont), Junior Membership Award; and J. A. Quinn (Princeton Univ.), the McLaren White Award. The awards were conferred by President Kirkbride.

Outstanding event of the banquet was the address given by the Secretary of Commerce, Honorable Sinclair Weeks. Highlights of his talk appear elsewhere in this story on the New York Annual Meeting.

Chemical Engineers' Capers

After the banquet, the dance. This had a real, sophisticated "New York Night Club" atmosphere—without the usual price tag, however. From the sidelines, looking over the scene of tables ringing the center dancing area crowded with swaying couples, an outstanding authority (in an aside) paid tribute to the beauty of chemical engineers' wives!

It can be truthfully reported that at this Institute meeting, the chemical engineers *danced*. There were enough ladies present to make possible not only a thoroughly presentable showing on the dance floor, but also at the same time to provide centers of conversation at the tables.

Digest of Secretary Weeks' remarks appears on pages 57 & 59.

Institute lecture by Manson Benedict will appear in February C.E.P.

Professional progress award lecture by John R. Bowman to appear in later issue.

Hal I. Wolff (Co-Chairman, Hotel & Meeting Rooms Comm.).

Ralph Cohen (Chairman, Finance Comm.).

PANEL DISCUSSION ON RUBBER PLANT DISPOSAL

The Washington, D. C., Local Section will on February 16th sponsor an evening panel forum on the synthetic rubber plants disposal program at the National Press Club. Discussion will be by leaders of the rubber and petroleum industries, as well as Congress and the Department of Defense.

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In 1950 the Atomic Energy Commission submitted to Girdler laboratory data on a process to produce heavy water. Girdler reviewed the existing data, bench-tested, pilot-planted, estimated, engineered, procured equipment for, and constructed an extensive, complicated, chemical processing plant at Dana, Indiana for the AEC. Upon completion of the pilot plant, AEC engaged the du Pont Company as the prime contractor and operator for the project; with Girdler continuing to carry out phases of work for engineering development, design, procurement, and construction. This vital project for our national defense became a "crash" program with greatly accelerated completion schedules. During the construction of this high-quality plant Girdler established an outstanding safety record.

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Industrial News

43 COMPANIES PLAN JOINT RESEARCH PROGRAM

The problems of designing and operating distillation units, common to almost all of the chemical process industries, are being studied under a joint research venture of 43 prominent chemical companies. Fractionation Research Inc., a non-profit organization of stockholder members, has constructed a new experimental distillation plant at their own research center in Alhambra, Calif. in which they can investigate the effects of tray design, system properties, and operating conditions on capacity and tray efficiency.

The basic information developed will be used both to revamp existing equipment for increased capacity or better separating efficiency and in the design of new columns that are less costly, more flexible, reliable, and more effective than those designed with existing knowledge.

While several companies have made attempts to secure the data necessary to predict such things as vapor-liquid handling-capacity and separating-efficiency under various loading conditions, the cost of a complete research program is too high for an individual company to justify. By pooling their resources the FRI members intend to accomplish what one alone could not afford to do. Membership in the organizaton is open to anyone that wishes to participate in the studies.

The program will be started with an investigation of various distillation devices, by means of a so-called simulator column, followed by a more exhaustive study in the new distillation unit of those devices that show promise and finally a full-scale test in actual plants to check and extend the experimental data.

A 66-inch, three-tray simulator column was privately built by C. F. Braun & Co. some time ago to study experimental tray designs. It will be used as a screening device for testing bubblecap-trays and other contacting devices. Bubblecap-trays due to their widespread use will be the first units investigated.

The experimental distillation plant is a 48-inch, ten-tray distillation column. This was achieved and constructed by Braun and is adjacent to their own research center in Alhambra. They are a member of FRI and will provide the engineering and operating staff.

Binary systems will be used first to test tray designs, since with these systems analysis is simple and reliable. Sufficient studies will be made, however, with multicomponent mixtures to assure that the results of the binary systems are applicable to complex mixtures. Two mixtures now in use are n-butane with isobutane and cyclohexane with normal heptane.

FLUID HYDROFORMER NEARS COMPLETION

The world's second fluid hydroformer, to have a capacity of close to 13,000 BPD, is nearing completion in East Chicago, Illinois. Located at the Cities Service Refinery the new unit will be used principally to upgrade low octane naptha to high octane gasoline although it may be used to produce aromatic materials such as benzene, toluene, and xylene.

The large tower on the left marks the site of the combination naptha-recycle gas furnace and behind the storage drums in the center is the main group of vessels in the plant, the reactor-regenerator section. The spent catalyst stripper atop the reactor is visible.

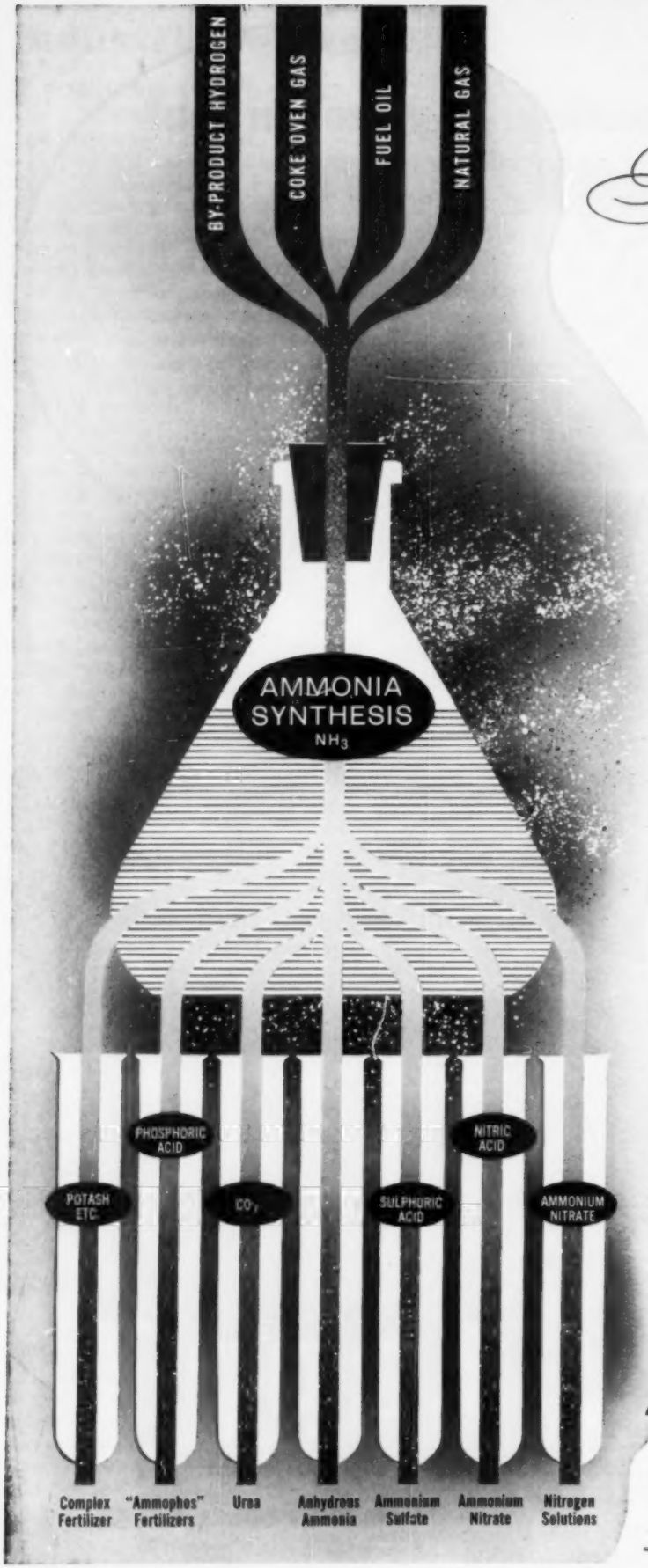
This hydroformer was designed and is being constructed by the M. W. Kellogg Co., and will be followed by a 17,000 BPD hydroformer at the Cities Service refinery in Lake Charles, La.

U. S. STEEL INTEGRATES AMMONIA PLANT

A new 200-ton per day ammonia plant will be integrated into the Geneva, Utah plant of the United States Steel Corp.

The new plant will have a capacity for producing 70,000 tons of ammonia annually and will produce anhydrous ammonia and ammonium nitrate for the expanding industrial and agricultural markets in the Intermountain and Pacific Northwest areas. Coke oven gas being produced at the Geneva plant will be used as a source of hydrogen in the ammonia plant.

Construction of the plant will begin early in 1955 and is expected to be producing in 1956. The contractor for construction is the Chemical Plants Division of Blaw-Knox.



Fluor combines process experience with two proven methods to design and build better ammonia plants

Fluor is presently engaged in designing and building four ammonia plants representing a total investment of over $40,000,000. Each plant will use a different raw material: electrolytic and other by-product hydrogen, fuel oil, natural gas, and coke over by-product gas. There is a wide range of source materials that may be used in ammonia plants designed and built by Fluor.

The Fluor ammonia synthesis process incorporates a pure synthesis gas feed with moderately high pressures to give very high yields of ammonia in a compact, easy-to-operate unit. The equipment features the world renowned Claude converter. By special arrangement, Fluor draws upon the valuable experience of L'Air Liquide of France which, for more than 30 years, has developed high pressure techniques to a high degree of perfection while building and operating its own ammonia plants, in addition to building plants for others throughout the world.

Fluor is licensed to employ the Texaco Partial-Oxidation Process, the most advanced means of manufacturing hydrogen from natural gas, fuel oils, and other hydrocarbon stocks. Fluor is also experienced in the processing of coke-oven gas for the preparation of hydrogen for available synthesis.

This broad ammonia experience plus Fluor's recognized ability to design and construct processing facilities is your key to a better ammonia plant.

BE SURE WITH

FLUOR

THE FLUOR CORPORATION, LTD
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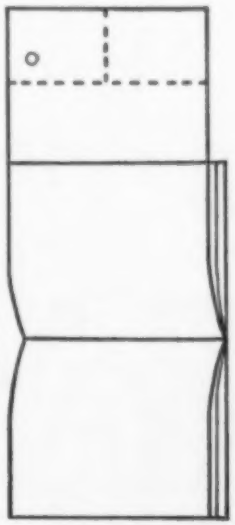
Just a moment is needed to learn how to use this insert. When looking through the front part of the magazine pull the folded portion of the insert out to the right, and the numbers on the post card are convenient for marking. THEN . . . .



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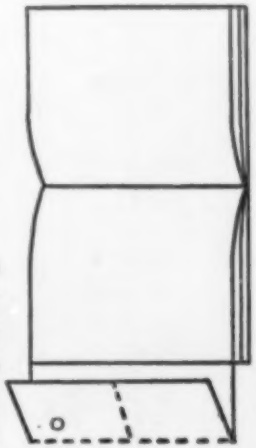

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CHEMICAL ENGINEERING PROGRESS
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New York 36,
New York

PRODUCTS

IFC Distribution Facilities. Location of plants, storage stations, & warehouses provide constant source of supply of chemimcal needs. Carbide and Carbon Chemicals Co., Div. Union Carbide and Carbon Corp.

2JA Centrifugal. Maxi-Flex centrifugal handles one material continuously or several materials intermittenly. Tolhurst Centrifugals, Div. American Machine and Metals, Inc.

3R Rotary Sifter. All-metal rotary sifter gives clean, thorough separations, dust-tight, sanitary operation. B. F. Gump Co.

4A Autoclave. Impeller of Dispersimax pumps gases continually through liquid in constant agitation in presence of suspended catalyst. Autoclave Engineers, Inc.

5A New Quarters. To serve the gas, power, petroleum & chemical industries more efficiently, a modern new home. J. F. Pritchard & Co.

6L Metering Valve. Needle point in this valve just 8° wide & requires 20 turns to move the point ⅜ in. Hoke Inc.

7A Air Preheater. Operates on continuous regenerative counterflow principle. Heat transfer from waste gases to incoming cold air made as rotor revolves. The Air Preheater Corp.

8A Valves. Gate, globe & angle pattern corrosion-resistant valves in 18-8 SMo & Craneloy 20. Crane Co.

9A GLC Anodes. Peak performance is production experience of producers of chlor-alkali who use GLC anodes. Great Lakes Carbon Corp.

10L Stainless Steel Fittings. Screwed, flanged, welded types, plus patented fittings designed for assembly without threading, welding or flaring. Cooper Alloy Corp.

11A Temperature Control. Dowtherm, the modern heat transfer medium. Used to develop new & improve old products through better control. The Dow Chemical Co.

12A Conveyor Dryers. Precision-built, pre-fabricated structure, improved housing panels, super-power fans feature these conveyor dryers. National Drying Machinery Co.

13A Technical Literature. Bulletins describing various items manufactured are available from Otto H. York Co., Inc.

14L Oil Reclaimer. Simple, economical & efficient method of restoring contaminated lubricating & sealing oil. The Hilliard Corp.

15A Indicating Controller. New M/41A model offers snappy on-off action, good proportional control, adjustable action .25% to 25%. The Foxboro Co.

16A Canned Rotor Pumps. Low upkeep, no fluid losses, unique design combining pump & motor feature these pumps. Chempump Corp.

17A Celite. Filtration using Celite assures clarity. Filter cake hundreds of times finer than finest wire mesh. Johns-Manville.

18L Ball Bearing Swivel Fittings. Designed with built-in stamina for tough jobs. High safety factor. Emsco Mfg. Co.

19A Petrochemical Plant. A very special-purpose model now being process engineered & designed, illustrated. M. W. Kellogg Co.

20A Catalytic Combustion Units. Operate efficiently at temperatures to 1500° F. using nickel-chromium alloys. The International Nickel Co., Inc.

21A Zipper Distributing System. Handles carbon black by means of zipper belt. Units operate in the open. Stephens-Adamson Mfg. Co.

22L Drying Equipment. Every installation backed by analysis of problem, knowledge of sound design, systems which perform according to specifications. Proctor & Schwartz, Inc.

23A Syncrogear Motor. Cantilever anchored on non-yielding one-piece base, mounting stresses absorbed, gear & motor distortion-free. U. S. Electrical Motors, Inc.

24A Corrosioneering News. Quick facts about services and equipment manufactured. The Pfaudler Co.

25A Super-D-Hydrator. High speed dehydrating centrifuge provides external control of flow rate, crystal size, slurry concentration. The Sharples Corp.

26L Chemical Feeder. Flexibility of feeders permits accurate feeding of many chemicals at rate of few drops to 60 gal./hr. Manzel Div. of Frontier Industries, Inc.

28A Stainless Steel. Varying amounts of chromium & other metals alloyed with steel give stainless specific all-the-way-through character for use in special problems. Sun Shipbuilding & Dry Dock Co.

29A Liquid Filters. Staynew filters stop rust, pipe scale & other impurities. For use in many industries. Dollinger Corp.

30A Vacuum Rotary Dryers. Low temperature drying with agitation & recovery of solvents accomplished. Buflovak Equipment Div., Blaw-Knox Co.

31A Graphite Equipment. Equipment fabricated from Karbate impervious graphite inert to wide range of corrosive conditions. National Carbon Co., Div. Union Carbide and Carbon Corp.

32A Filters. This horizontal filter filters to clarity at rates to 45,000 gal./hr. & maintains that clarity. Niagara Filters, Div. of American Machine and Metals, Inc.

33A Alite. A material said to have dimensional stability at temperatures beyond 2000° F., with zero porosity. U. S. Stoneware Co.

35A Electrically Heated Equipment. Indirect heating equipment using electric heat available in sizes to 1,000,000 B.t.u. Struthers Wells Corp.

36A Scrubber. A tail gas scrubber that handles hydrochloric acid & chlorinated solvents at high temperatures. Electro Chemical Engineering & Mfg. Co.

39R Safety Heads. Variety of possible uses limited only by number of ways in which compressed air, gas or liquids are handled. Black, Sivalls & Bryson, Inc.

41A Vacuum Filters. Prevents cake cracking, improves washing, & on some filter cakes reduces moisture 8 to 10%. The Elmco Corp.

43R Gaskets. Impervious to acids, caustics, solvents, Teflon jacketed gaskets. Suit every connection problem. United States Gasket Co.

44L Gland Packed Plug Valves. Can be repacked under full operating conditions. Adjusting nut prevents sticking or freezing. Hamer Valves, Inc.

45A Heavy Water. Plant for production of heavy water built for A.E.C. on their basic data. Service available for building any desired plant. Girdler Co., Div. National Gas Co.

Chemical Engineering Progress

Numbers followed by letters indicate advertisements, the number corresponding to the page carrying the ad. This is for ease in making an inquiry as you read the advertisements. Letters indicate position—L, left; R, right; T, top; B, bottom; A indicates a full page; IFC, IBC, and OBC are cover advertisements.

Be sure to give name, address, position, etc.

Remember, the numbers on the upper portion of the card bring you data on only the bulletins, equipment, services, and chemicals reported in these information insert pages. The lower portion of the card is for the advertised products, and is keyed not only to advertising pages, but also to the memory-tickling list under the heading Products.

47A Valve. Body & plug both of porcelain. Special spring-loaded cushion seating prevents damage & warns when seal is tight. Lapp Insulator Co., Inc.

48A Ammonia Plants. Combining process experience with two proved methods results in better designed & built ammonia plants. The Fluor Corp., Ltd.

53A Spray Dryers. Illustrations of 21 recent Spray Dryer Installations. Bowen Engineering, Inc.

57R Slurry Pump. Built with a casing liner, disc liner & impeller made of manganese steel, Ni-hard, etc. for heavy abrasive slurries with solids in suspension. Lawrence Pumps, Inc.

59R Processing Equipment. Rupture disks, centrifugal pumps, Graph-I-Tite developed during 1954 provide new & improved processing equipment. Falls Industries, Inc.

60L Filter Presses. New issue of a book on jobs for filter presses that improve processing. T. Shriver & Co., Inc.

62L Sizing Machinery. Accurate sizing of granular materials accomplished by use of pocketed discs or indented cylinders. Hart-Carter Co.

63R Air Classifier. Called Gyrotor an air classifier designed for close product control in dry grinding or separating. Hardinge Co., Inc.

64L High-Alloy Castings. Melt, castings & finishing controlled & quality tested by staff. Products are heat, corrosion & abrasion resistant. The Duraloy Co.

65R Turbine Pumps. Unlimited flexibility of installation, with discharge heads for any system on these vertical turbine pumps. Johnston Pump Co.

(Continued on back of this insert)

Please do not use this card after April, 1955

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Advertisers' Products

IFC	2JA	3R	4A	5A	6L	7A	8A	9A
10L	11A	12A	13A	14L	15A	16A	17A	18L
19A	20A	21A	22L	23A	24A	25A	26L	28A
29A	30A	31A	32A	33A	35A	36A	39R	41A
43R	44L	45A	47A	48A	53A	57R	59R	60L
62L	63R	64L	65R	67R	68L	69R	70TL	70B
71R	72TL	72BL	73L	73R	74TL	74BL	75R	76L
77R	79TR	79BR	81BL	81R	82TL	82BL	83TR	83BR
86BL	87A	IBC	OBC					

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19A	20A	21A	22L	23A	24A	25A	26L	28A
29A	30A	31A	32A	33A	35A	36A	39R	41A
43R	44L	45A	47A	48A	53A	57R	59R	60L
62L	63R	64L	65R	67R	68L	69R	70TL	70B
71R	72TL	72BL	73L	73R	74TL	74BL	75R	76L
77R	79TR	79BR	81BL	81R	82TL	82BL	83TR	83BR
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January, 1955

PRODUCTS (Continued)

67R **Diaphragm Valves.** Unique design completely isolates working parts of valve from flow. No packing to tighten or replace. Hills-McCanna Co.

68L **Plastic Pumps.** Flex-i-liner pumps handle corrosive solutions & abrasive slurries with ease because design eliminates a number of parts. Vanton Pump & Equipment Corp.

69R **Air Pollution.** Increasing stack height possible using wind operated, automatic controller called Windtrol. Bendix-Friez Instrument Div., Bendix Aviation Corp.

70TL **Filtration.** New catalog details all the facts you must know about filtration. For easy reading & classified for instant reference. D. R. Sperry & Co.

70B **Bevel Gear Universal Joints.** Conesco specialties include also Flowrites, fiber plugs, heat exchangers & others. Condenser Service & Engineering Co., Inc.

71R **Mixers & Blenders.** Every grinding & mixing need met using one of the available units. Paul O. Abbé, Inc.

72TL **Fin & Pipe Coils.** Fabricated of stainless steel parts handle all types of corrosive air mixtures to be heated or cooled. Rempe Co.

72BL **Spray Nozzles.** A nozzle for every need. Choice of thousands which give exact spray pattern. Spraying Systems Inc.

73L **Books.** Volumes on Chemical Process Principles & Synthetic Rubber. Also Minerals for the Chemical and Allied Industries. John Wiley & Sons. Inc.

73R **Dust-Tite Valves.** A self-cleaning, free flowing, dust-tite valve. Machined to close tolerances. General Machine Co. of New Jersey.

74TL **Metal Products.** Complete plants, pilot plants, also vacuum rectifying column designed to operate either batch or continuous. Artisan Metal Products, Inc.

74BL **Hoppers.** Built of rustproof, non-oxidizing materials to prevent contamination, hoppers 9 x 6 x 6 ft. which hold & feed 6,000 lb. of polystyrene. Carl N. Beetle Plastics Corp.

75R **Protective Coatings.** Polyclad 933-3 gives an 8 mil. thickness with 1 prime, 2 finish coats. Non-toxic Carboline Co.

76L **Antifoam Emulsion.** Cooling time reduced 25%, vacuum concentration capacity increased 60%. Dow Corning Corp.

77R **Rubber-Lined Filters.** A unit of two of these filters solved the problem of rapid clogging of sand in a spent brine disposal well. R. P. Adams Co., Inc.

79TR **Filters.** Horizontal plate filters for fine filtering with positive cake stability. Sparkler Mfg. Co.

79BR **Ejectors.** Maximum vacuum per pound of steam provided by steam-jet ejectors. Ingersoll-Rand Co.

81BL **Catalyst Filters.** Complete catalyst retention, low pressure drop, hi-temp service obtained with use of MMC catalyst filters. Micro Metallic Corp.

81R **Coolers.** Custom built coolers for chemical process liquids using any common refrigerants or brines. Richard M. Armstrong Co.

82TL **Radioisotopes.** Use of radioisotopes in your plant provide powerful & versatile tool for quality control, product improvement, etc. Foster D. Snell, Inc.

82BL **Steam Jet Ejectors.** Also condensers & vacuum equipment. Corrosion-resistant parts interchangeable with standard parts. The Jet-Vac Corp.

83TR **Jet Mixer.** Use of this mixer assures complete circulation, with rapid & uniform treatment of material. Hermes Machine Co.

83BR **Plasticizer Oil.** Hydrocarbon Panaflex plasticizers have excellent compatability with all GRS rubbers, also Neoprene & Buna N types. Pan American Chemicals Div. Pan American Refining Co.

86BL **Mini-Lab Assembly.** For small scale unit operations such as reaction, distillation, & unique combinations. Ace Glass Inc.

87A **Contest.** Extensive line of jet cooling units, capacities to 3,000 tons of refrigeration. Croll-Reynolds Co., Inc.

IBC **Flow Control.** Motor-driven controlled volume pump has air-controlled variable drive, which adjusts automatically to control reaction rate. Milton Roy Co.

OBC **Mixing.** To get optimum results in liquid-liquid contacting consult Lightnin catalogs. Mixing Equipment Co., Inc.

CHEMICALS

1 **Mo-Silicone Glassware & Vacuum Grease.** Preliminary data sheet from The Lockrey Co. on Mo-Silicone Glassware & Vacuum Grease. Said to represent a new principle in lubrication of vacuum appartus. Combines chemical inertness & excellent temperature-viscosity relationship of silicone liquids with lubricating qualities of molybdenum disulfide. Also used as a seal & thread compound. Ordinary cleaning will not remove substance from glassware.

2 **Trimethylene Chlorobromide.** Michigan Chemical Corp. has developed & is producing in commercial quantities trimethylene chlorobromide (1-bromo-3-chloropropane). Compound makes possible synthesis of several compounds of trimethylene group. Controlled to assure high purity required of pharmaceutical intermediates. Quantities to & including carload lots, in 700 lb. nonreturnable drums.

3 **Maleic Anhydride.** Monsanto Chemical Co. 20-page booklet deals with maleic anhydride. A section gives data on production & use of unsaturated polyester resins for low pressure lamination. Diels-Alder reactions of substance also other organic chemical syntheses discussed.

4 **Synthetic Rubber Grade Styrene Monomer.** Announced by Koppers Co., Inc. immediate availability of synthetic rubber grade styrene monomer. Has minimum styrene content of 99% & not more than 0.020% sulfur content.

5 **Natural Rubber Latex.** H. L. Blachford, Inc. named sole U. S. agent for Revertex the natural rubber latex made in the Far East. Substance is a heat concentrated latex of about 73% solids. Illustrated brochure describes compounding, processing, qualities. Lists properties, other pertinent information.

6 **Liquid Neoprene Coating.** Announced by Palladium Mastic Corporation of America a self-curing liquid neoprene coating with good corrosion resistance. Recommended for protection of new or old equipment &

(Continued on page 54)

CHEMICALS

(Continued from page 52)

structures whether of metal, wood or concrete, against splash, fume or spillage of non-oxidizing inorganic acids, alkalies, inorganic salts & most polar solvents.

7 **Metallic Stearates.** Technical booklet from Synthetic Products Co. on metallic stearates contains advanced data on physical & chemical properties of various types. Also features field & research experience gathered over years.

8 **Petroleum Wax.** Said to be highly refined & tailor made to prevent surface checking & cracking of rubber products. Sun Oil Co. Anti-Chek. Technical bulletin discusses composition, applications, test data.

9 **Foamed Insulation.** Development of a series of foamed in place insulation, flotation & structural reinforcing products announced by Atlas Mineral Products Co. Called Urefoam material is supplied as two-package unit. Expands up to 30 volumes. Fills most intricate shapes.

10 **Fatty Chemicals.** Available from Archer-Daniels-Midland Co. 40-page technical catalog of fatty chemicals. Booklet is written from functional standpoint & designed to streamline reference & specification. Subdivided into four major product classifications. Sections classified into reaction data, specifications, composition & application information. Includes working charts & test definitions.

11 **Teflon Sealing Compound.** A chemically inert Teflon thread sealing compound for use in sealing threaded assemblies of stainless steel and other ferrous & nonferrous alloys, plastic, rubber & other fittings from Eco Engineering Co. Seals without cementing, prevents thread seizures, will seal with low-torque in addition to other features. Comes in 2 or 4 oz. jars.

12 **Flocculating Agent.** Said to be an advance in separation & filtering of water dispersed solids in industry is Separan 2610 from Dow Chemical Co. Of particular interest to mining industry material removes solids from water solutions in many industrial applications. Said to decrease material losses up to 80%, & increase total product recovery by 5%. Samples, technical information & directions available.

14 **Liquid Polymer/Epoxy Laminating & Casting Compounds.**
15 (14) Booklet from Thiokol Chemical Corp. on laminating compounds contains most recent information on starting formulations & properties. (15) Thiokol's booklet on liquid polymer/epoxy casting compounds contains information on these materials.

16 **Ammonia Synthesis Catalyst.** 25% increase in production capacity in preparation of ammonia synthesis gas from natural gas provided by use of Girdler Co. G-29 catalyst. At previous production rates use has reduced reaction temperature 100° F without loss of efficiency. Contains 27% nickel which becomes active in reforming hydrocarbons at 1,100 to 1,850° F. Material is preshrunk & supplied in form of ½ or ¾ in. extrusions in ¾ in. ring formation.

17 **Phthalic Anhydride.** Monsanto Chemical Co. bulletin on phthalic anhydride contains sections on application characteristics, in resins, in plasticizers, in organic syntheses, handling methods.

18 **Glycol.** Diethylene & triethylene glycols are subject of technical bulletin from Carbide and Carbon Chemicals Co. Substance used to plasticize composition cork. Also in dehydration of natural gas to prevent formation of gas hydrates.

19 **Expansible Resins.** For use in preparation of silicone foam structures, a series of expansible resins from Dow Corning Corp. in form of ready mix powders. Contain premeasured proportions of resin, filler, blowing agent & catalyst resulting in melting of mixes, foaming & curing by themselves when heated. No other processing required.

BULLETINS

20 **Space Saving Filter.** Said to incorporate new filtration principle & give double filter area & volume of present units announced by Bart-Messing Corp. Filter constructed of corrugated stainless steel & wire mesh which supports unique filter bag. Bag available in variety of materials & suitable for use with any type solution or liquid. Called Sel-Rex entire element is attached to cover of tank. Easily moved for inspection, cleaning or replacement.

21 **Needle Valves.** Carpenter Valve Corp. announces a complete new line of forged needle valves with universal outlets featuring micrometer thread stainless steel stems for fine metering. Called Bull-Dog needle valves the bodies are forged from brass, stainless or carbon steel. Wide range of optional machinings on outlets facilitate economic installations. Also available in mountings for instrument panels.

22 **Electromagnetic Pump.** Designed to move liquid metals within cooling or heating systems to force liquid metals into forms in die-casting operations announced by Callery Chemical Co. Operates on electromagnetic principle, has no moving parts or packing glands. Can be operated from single phase, 60 cycle a.c. voltage.

23 **Steam Trap.** Yarnall-Waring Co. introduce a ½" Yarway impulse steam trap 20-A designed to handle light condensate loads. Will not freeze or air bind on steam tracer line service. Said to give good results on applications like small platens, autoclaves, unit heater.

24 **Packless Solenoid Valves.** Two-way packless solenoid valves for control of flow of air, gas, water, light oil & other non-corrosive fluids from Automatic Switch Co. Available normally closed or normally open, with standard, watertight, or explosion proof solenoid enclosures. Illustrated bulletin shows diagrams, lists pressures, electrical characteristics.

25 **Platform Scale.** From Weighing Components, Inc. an electric platform weighing scale utilizing strain gauge load cells & pneumatic tare weight permitting inexpensive & accurate net weight measurement. Adaptable for either batch weighing or continuous process control. Folder gives other pertinent data.

26 **Pneumatic Control.** Sterling Motors, Inc. announce a pneumatic control for the Speed-Trol variable speed transmission. Utilizes a Cono motor & provides automatically controlled drive for process operations involving variables of pressure, temperature, liquid level, proportional flow & control of rewind. Simple design said to be accurate & reliable. May be had with standard or special electrical characteristics.

27 **Bubble Tray.** Called Uniflex & licensed by patentee, Socony-Vacuum Oil Co., Inc. to manufacture & sell, a removable section bubble tray simply designed & providing high capacity at minimum cost. Proportioned to provide availabie slot area of from 12 to 14% of superficial tower area. Entire length of slotted section effective. No interference from issuing vapors. Badger Mfg. Co.

handling of interest. Lists 86 dry pulverized materials &

contraction as a result of temperature changes. Rating

28 **Thermodynamic Steam Trap.** Thoroughly field tested thermodynamic steam trap now available from Sarco Co., Inc. Not an impulse trap. Closes tight on no load; operates against back pressure to 50% of its inlet pressure. Discharges at steam temperature. For use in steam mains & separators. Said to be extremely resistant to water-hammer shock. Corrosion resistant.

29 **Spray Dryers.** Leaflet from Proctor & Schwartz, Inc. describes types of dryers to serve all segments of the process industries. Each unit detailed & illustrated. Complete engineering-manufacturing facilities available.

30 **Blenders.** J. H. Day Co., Inc. booklet on blenders for mixing of powders, paste, & liquids includes general description, graphs, charts. Tanks may be equipped with heating or cooling jackets for 40, 60 or 80 lb. pressure. Hand wheel or air operated flush valves available.

31 **Controlled Volume Pumps.** Milton Roy Co. 24-page bulletin reports on controlled volume pumps in process instrumentation & describes & illustrates how these pumps may be used as flow ratio, & final control elements. Various sections cover fee, basic, open or closed loop, composite, special, & integrated systems, in addition to much engineering data.

32 **Industrial Waste Treatment Equipment.** From Ralph B. Carter Co. leaflet describing types of equipment for treatment of water, sewage & industrial waste. Complete information available on specific units. Engineers & field specialists available for consultation.

33 **Compounding Plants.** Illustrated binder insert bulletin from Poulsen Co. on Uni-Blender compound plants for mixing, blending, & package drying, free-flowing, powdered materials including formulas involving liquid impregnation. Two types. Construction features cut-in hopper with dust hood & rotary sifter; continuous flow, closed circuit, self-cleaning conveyor elevator; splitter valve; improved design horizontal ribbon mixer.

34 **Telemetering.** Described in detail in illustrated bulletin from Motorola, Inc.—selective telemetering. Information available continuously or as selected. Shared use of telemeter communication channels with supervisory control systems permits remote control of valves; motors.

35 **Heat Exchangers.** Engineered to meet individual requirements, heat exchangers from Doyle & Roth Mfg. Co., Inc. Units of various ferrous & non-ferrous materials including aluminum, brass, copper, Monel, nickel, stainless & carbon steel.

36 **Diffusion Pumps.** Now available from Naresco Equipment Corp. catalog describing complete line of diffusion pumps. Lists characteristics of each type, including pumping speeds, operating pressures, blank-off pressures & forepressure limits. Operating charts on throughput & inlet pressures. Also photographs & drawings.

37 **Water Jet Eductors.** Water jet eductors are the subject of 3-color bulletin from Schutte and Koerting Co. which includes information on design, construction, application, & operation. Also material on methods of pumping & moving liquids, as well as handling of solids. Section includes nomograph for determination of need for special eductor if standard will not do job.

38 **Ammonia.** The six stages in processing sequence of ammonia, plus process flow diagram, & much information on process advantages form the subject of an illustrated booklet from Foster Wheeler Corp. Also lists typical summary of raw materials, chemicals, catalysts & utilities for ammonia synthesis.

39 **Dampening Valve.** A lightweight surge dampening valve, of inline construction said to prevent destructive dynamic hydraulic surges. Bulletin shows graph of rapid dampening action. At 5,300 lb./sq.in. surge valve dampened in 1/20 secfl Sterer Engineering & Mfg. Co.

40 **Process Plants & Units.** A complete service for design & construction of process plants & process units; design and/or fabrication of special processing equipment; vapor compression stills & other units, from Badger Mfg. Co. lists scope of services from project to production, describes facilities & products.

41 **Stainless Pipe.** Of interest to engineers & designers with problems involving stainless piping, bulletin from Tubular Products Div., Babcock & Wilcox Co. Application data, tensile properties, methods of bending & joining, flow diagrams included.

42 **Temperature Controls.** Bulletin covering model D-1S control for use in controlling temperatures to 1800° F from Burling Instrument Co., Inc. Operation illustrated & described. Also tube construction, switches, tube materials. Specification chart & flow diagram.

43 **Oil Burners.** High velocity burners for use in ovens, dryers, & kilns, discussed in leaflet from Thermal Research & Engineering Corp. Fuel oil vaporized within burner before being burned. Units said to provide high degree of cleanliness to products of combustion. Jet effect of burner gases said to better distribute heat down length of kiln.

44 **Research Facilities.** From Foster D. Snell, Inc. booklet entitled "Product Evaluation and Physical Testing." Lists company's specialized services in developing, improving, & evaluating products.

45 **Cast Stainless Alloys Data.** An up-to-date compilation of data sheets covering the properties of all popular grades of alloys used for corrosion resistant stainless steel castings now available from the Alloy Casting Institute. Listed are compositions, physical & mechanical properties.

46 **Acid-Alkali-Resistant Glass.** Now standard on glassed steel units for severe chemical service is an acid-alkali-resistant glass from Pfaudler Co. Described in Corrosioneering News from Pfaudler. Also discusses solvent recovery, mixing oil & water in glassed steel reactors with a 100% emulsion in minutes.

47 **Vertical Pumps.** Two types of vertical, encased, close-coupled pumps for handling hydrocarbons, hot or cold water, mild acids, basic & salt solutions, are described & illustrated in bulletin from Peerless Pump Division, Food Machinery and Chemcal Corp. Capacities to 3,000 gal./min., heads to 1,000 ft., drives as required, temperatures to 400° F. Features listed, schematic diagrams shown.

48 **Pressure Vessel Connections & Manways.** Lenape Hydraulic Pressing & Forging Co. have released new reference data on complete line of pressure vessel connections, manways, necks, nozzles. Gives detailed engineering information & specifications, in addition to tables & technical data.

49 **Liquid Level Gages.** Three standard types of Jerguson Gage & Valve Co. remote reading liquid level gages with convex & flat scale available. Bulletin shows how gages bring liquid level down to point where it can be easily seen. Protects equipment & prevents shutdowns. Design & construction features shown.

50 **Pneumatic Systems.** Executives, engineers, & purchasing agents in industries handling drying pulverized materials will find the bulletin from Fuller Co. on bulk pneumatic

SECRETARY OF COMMERCE CITES PROCESSING GROWTH

handling of interest. Lists 86 dry pulverized materials & indicates which of three Fuller systems best adapted to handle each material. Also names 24 fields using Fuller rotary compressors.

51 **Vapor Absorber.** Named Vape-Sorber & used wherever conditioned air & gases are required for maximum instrument accuracy & process efficiency. Unit from Selas Corporation of America available in wide range of capacities ranging from 100 to 2,500 cu.ft./min. provides continuous removal of petroleum vapors, dirt & liquids from air & gases. Bulletin.

52 **Motors.** Multi-color booklet from U. S. Electrical Motors Inc. illustrates 20 principal types of improved motors including uniclosed, totally-enclosed, explosion-proof with & without fan, varidrive; syncrogear.

53 **Refractories.** Selection of the best refractory for each important application in the ceramic industry is covered in booklet from Norton Co. Well illustrated it contains sections on materials available, crystolon kiln furniture, kiln & furnace parts, service, & engineering tables. Of special interest to plant managers, design engineers, & kiln foremen.

54 **Ohmart Cells.** A catalog from the Ohmart Corp. on their contributions to the application of radioactive energy in industry. Included are the cell for direct conversion of radioactive energy to electrical energy; the null system of measurement said to be first commercial instrument using radioactive energy for measurement of specific gravity in process industries; the strip source of radioactivity to produce linear response when measuring liquid level or interface position. Details of construction, operation, other data.

55 **Crushers.** Heavy duty standard crushers for use in reducing chemicals, pharmaceuticals, foodstuffs, plastics of all textures from Franklin P. Miller & Son, Inc. covered in leaflet. Accept chunks to 16 in.; crushed sizes ½ to 4 in. High crushing rate, automatic feed & discharge, low temperature rise features.

EQUIPMENT

60 **Recording Balance.** Sharples Corp. bulletin announces a new Universal recording balance designed for observation of small, rapidly changing forces applied to moving system of servo-controlled torsion balance.

61 **Chemical Pumps.** Newly added to line of Byron Jackson Co. pumps specifically engineered for handling acids & other corrosive chemicals. Four basic sizes, available in various motor & impeller combinations, capacity range from 20 to 400 gal./min. Complete rotating element, bracket & stuffing box assembly removable as unit without disturbing other parts.

62 **Electronic Counter.** Model 25 Flow Digitizer new with Potter Aeronautical Co. This computing electranic counter converts the digital output of the Potter flow sensing element to gallons, pounds, other desired units. Accuracy ±½% over wide ranges; as high as ±1/10% as constant flow rates. Employs only 11 thermionic tubes operated at fraction of their load. Tilt-front cabinet available where instrument is not panel mounted.

63 **Quartz Thermostat.** Said to be immune to chemical attack but sensitive to temperature a quartz thermostat from N. J. Thermex Co., Inc. Unit consists of outer chemically resistant quartz tube plus a contained liquid which actuates the contact mechanism by expansion & contraction as a result of temperature changes. Rating 5,000 watts at 120-140 volts. Tubes 6 to 36 in.

64 **300-Mesh Glass Screens.** Now available from Corning Glass Works, 300-mesh precision glass screens containing over 200,000 square holes small enough to be threaded by a human hair. Currently in use as part of a cathode ray tube. Screens offer sharper definition & simplify manufacturing & conductivity problems encountered with other materials. Fabricated from Fotoform glass.

65 **Filter.** Designed to provide high efficiency filtering with low pressure drop for commercial & industrial ventilating & air conditioning systems the Aerosolve filter from Cambridge Filter Corp. Also for use with critical process air conditioning in chemical, pharmaceutical, food processing, other industries where clean air is essential, & where high percentage of dusts or fumes must be kept from escaping.

66 **Steam Traps.** Complete line of low, medium, high pressure steam traps announced by Strong, Carlisle and Hammond Co. Called Hydro-Flex they are available in semi-steel, cast steel, & forged steel construction for use on all pressures to 2,500 lb./sq.in., temperatures to 1,000° F. Meets difficult operating conditions. Features dual fulcrum which powers valve lever.

67 **Liquid Meters.** Neptune Meter Company's bulletin No. 567 covers type S 400 series registers for industrial liquids in batching, blending, or inventory control. Avoids open handling of messy or hazardous liquids including chemicals, syrups, hot & cold water, oils. Process engineers will find interest in selection chart. List of 150 materials handled.

68 **Vacuum Furnace.** An induction-heated furnace offered by Naresco Equipment Corp. Available with vertical or horizontal shell, it is a self-contained furnace for research & development purposes. Provided with coaxial power feed-through & means for adding additional charge or alloying material during melting without loss of vacuum.

69 **Displacement Pump.** A low-cost gearless, multi-purpose, rotary type displacement pump designed & manufactured by Eco Engineering Co. now available with self-lubricating carbon-graphite impeller. Advantages are self-lubrication of impeller; chemical inertness of impeller preventing product contamination. Capacities 1 to 10 gal./min., pressures to 150 lb./sq.in. Recommened for water systems, crop spraying, chemical pumping operations. Housing available in variety of materials.

70 **Tubeaxial Blower.** Fabricated from polyvinyl chloride & used for expelling corrosive air, fumes & gases, a 14 in. tubeaxial blower from Industrial Plastic Fabricators, Inc. All-plastic impeller blade of blower has spinner cap aerodynamically balanced to insure smooth, vibration-free, high speed operation. Drive shaft, pulley, belts & sealed bearings totally encased. May be installed vertically or horizontally. Model has ¾ hp. motor either 3- or 1-phase.

71 **Vibrating Screen Separator.** Tangential discharge spouts replace rectangular shape spouts on new Southwestern Engineering Co. vibrating screen separator. Uses unique gyratory motion imparted by vertically mounted motor. Material fed to screen surface separated in vertical flow pattern.

72 **Heating Coil.** Simultaneous fast heating & mixing are made possible through use of a coil with hollow shaft

(Continued on page 58)

SECRETARY OF COMMERCE CITES PROCESSING GROWTH

"The growth of the chemical process industries has proved that you people have been working, and working intelligently in a great industry," said Secretary of Commerce Sinclair Weeks to the A.I.Ch.E. at the Annual Awards Banquet on Dec. 14 in the Hotel Statler, N. Y. Speaking as honored guest Mr. Weeks went on to say "your industry is not only the most rapidly expanding but also one of the largest and most important in our economy. All of the 72 industrial groups encompassed in the interest of our department have increased their demands upon your industry every year and you have responded to their requirements. You have been enjoying an annual growth of 10% with a volume of 21 billions and it is expected that you will go to 30 billions by 1960."

Planning for the roll of business in defense and for a mobilization base, is a function of the Business Defense Services Administration, a section within the Department of Commerce. This group has been building up a business approach organization, and works in close cooperation under the guidance of the Office of Defense Mobilization. A new defense materials system has been devised by the DSA to take place of the old control materials plan. Also involved is the handling of tax amortization certificates and regulations and procedures governing stock piling.

An example of how their stock piling operation can assist business and employment in an emergency was brought out by Mr. Weeks. He told of a situation arising out of recent copper mine strikes both in this country and in Chile which threatened the closing of fabricating shops lacking the necessary copper. The available stockpile of copper was thrown into operation to supply fabricators and to help them keep their doors open until material coming from the mines at the termination of the strike could place them back in normal operation.

"The year drawing to a close has been one of adjustment from war to peace and everybody realizes that such a shift had to come after the rapid buildup of military production in Korean fighting. . . . I think something went wrong with the pessimists' predictions that there would be a change leading to a depression after this conflict. The members of the administration have felt that private enterprise could do the transition job successfully if encouraged and helped by government. I think that later events proved that they were right

(*Continued on page* 59)

EQUIPMENT

(Continued from page 56)

& flat spokes acting as paddles. Hollow shaft & coil are in an integral assembly permitting steam to be carried through shaft & coiled to promote heating. Made of stainless steel for mixing food products or those with acid or corrosive content. Suggested for sugar refining, oleo blending, cattle feed mixing, paper mill processing & mixing of dairy products. Rempe Co.

73 **Clad Steel Plates.** Facts about the economics possible in using clad steel plates are contained in an easy-to-read publication from Lukens Steel Co. Discusses 16 standard alloy claddings on variety of backing steels & demonstrates how designers & fabricators can save on equipment costs.

74 **Sectional Bag Conveyor.** Added to line of Stephens-Adamson Mfg. Co. a sectional bag conveyor. Heavy duty unit designed for handling bags, boxes, & cartons. Available in 18 or 24 in. belt widths with standard 20 ft. interlocking sections. Drive units have tail shaft mounted sprocket for powering drive units. Designed for fixed horizontal conveying but easily adaptable for portable or inclined conveying. Standard roller spacing is 16 in. but has decking punched with variable spacing. Illustrated bulletin.

75 **Teflon Gasket.** New in gasket construction & said to eliminate flow restriction & turbulence in the line, as well as gasket rupture at high temperature due to entrapped air are Crane Packing Co. FreeFlow gaskets. Made of Teflon gasket is adaptable to most corrosion services plus temperature variations from —100° to +482° F., depending on insert material. All shapes & sizes for many applications. Recommended for use in glass-lined porcelain, & pyrex equipment including kettles, pipes, nozzles.

76 **Pressure Difference Switch.** From Barksdale Valves pressure difference switch Meletron Model 462. Senses accurately pressure differences from 0 & 99 lb./sq.in. between two pressures within range of .05 to 100 lb./sq.in. Will actuate an electric circuit on increase or decrease of any predetermined pressure difference within range of switch selected. Adjustable ratchet makes adjustment easy. Operates in any position.

77 **Color Lakes.** Said to have exceptional lightfastness & brilliance series of organic color lakes introduced by Harmon Colors of B. F. Goodrich Chemical Co. Noted for durability & stability under severe weather conditions. Named Harmon Indo colors in automotive formulations they have been extensively exposed in hot climates. Includes wide color range. Said to be first offering of specially conditioned & finished vat colors for use as pigments.

78 **Rubber Drum Inserts.** Recently made known by Automotive Rubber Co., Inc. is production of removable rubber drum inserts called Drumserts for 55 gal. drums. Inserts are preformed, independent linings made of compounded neoprene & sheet rubber. Set in drum the lip provided on insert is lapped over top of drum & pulled taut. Makes any 55 gal. drum or barrel capable of holding acids & other corrosive materials. Also electroplating solution makeup, acid dip, pickle, strip operations.

79 **Liquid Meter.** Featured by Neptune Meter Co. on their liquid meter is an electrical switch to control pumps, valves, agitators, which is built-in, explosion proof, actuated automatically when desired quantity of liquid has passed through. May be used to turn pumps off or on, actuate solenoid valves, start agitators, control cycling operations by use of suitable relays. Available either with or without mechanically coupled Auto-Stop valve, also actuated by tripping mechanism in register.

80 **Thermistor Actuator.** Said to be a first indicating temperature controller to utilize a thermistor as sensing element, now available from Fenwal, Inc. Brochure lists performance specifications, covers design features. Features include selective control, response differential, good electrical & mechanical stability.

81 **Package Chillers.** New PC units completely wired, charged with Freon & factory tested for chilled water air conditioning systems, drinking water or beverage cooling applications, or industrial water cooling uses. Models 2 through 15 HP. Construction gives large capacity without bulk. Bulletins available. The Heat-X-Changer Co.

82 **Automatic Blender.** A two component blender designed to provide industry with complete equipment package for on stream blending. Simplified, & standardized it is suited for use in caustic dilution, asphalt blending, cutting heavy fuel oil, & blending of butane & gasoline. Delivers uniform blend directly to tank trucks, card, ships, or storage. Proportioneers, Inc. Folder.

83 **Thermometers.** Vapor-pressure actuated thermometer systems which record on uniform charts now available from Bristol Co. Said to combine advantages of freedom from ambient temperature effects, fast response, simple control attachments. Patented varying-ratio linkage converts non-linear vapor pressure-temperature curve into linear deflection of recording pen. Available in ranges from —20 to 600° F.

84 **Solenoid Valve.** A stainless steel solenoid operated two-way valve with good corrosion resistance & designed to control gases and liquids from Automatic Switch Co. Heavy duty construction of three moving parts suitable for operation at 400 times/min. Internal parts accessible without removing valve body from pipe line. Removal of valve bonnet permits sterilizing or cleaning.

85 **Flexible Hose.** Revolutionary type of flexible hose for transfer of chemicals, gases, liquid food products from Plastiflex Co. Made of two plies of polyethylene film which enclose a spiral of stainless steel wire. If additional reinforcement is desired hose may be armored with flexible stainless steel braid or heavy plastic. Polyethylene film is Visqueen from Visking Corp.

86 **Polyvinyl Chloride Equipment.** Now available from Atlas Mineral Products Co., standard sized self-supporting tanks & chemical processing equipment fabricated from reinforced chemical resistant polyester resins & unplasticized polyvinyl chloride. Products carry trade name of Plastaloy & Ampcoflex.

87 **High-Pressure Equipment.** Catalog from American Instrument Co., Inc. on recently developed high-pressure equipment for pressures to 100,000 lb./sq.in., temperatures to 1,000° F. Described are pilot plants, reaction vessels, valves, fittings, tubing, pumps, compressors. Also special devices & pilot plants.

88 **Motors.** Called Super T, a line of d.c. motors is announced by Reliance Electric and Engineering Co. Said to give the dynamic response usually found only in specially designed machines. Sizes 20 to 100 H.P. Illustrated bulletin describes features, lists selection data, dimensions, other data.

SECRETARY OF COMMERCE

(*Continued from page 57*)

in trusting the dynamic power of our free economic system. I believe that the peddlers of doom who have been around this year now admit that business is on the upgrade. The current job picture looks good.

"We expect in Washington that next year is going to be a good year—better than this year—with excellent prospects. The construction industry has an estimated 7% increase for next year over this year. I am convinced we can enter into a ten-year era of tremendous economic growth and individual well being.

"Of every dollar the government spends," said Mr. Weeks, "66 cents goes for defense, which includes stockpiling, atomic energy, and foreign military aid. We then spend 23 cents for four things —grants to states, agricultural support, interest on the debt and veterans payments. The remaining 11 cents runs every other department and agency of Government including legislative and judicial branches. With the cold war situation as it is, it is a difficult problem to balance the budget."

Mr. Weeks urged the Institute members to take interest in political action by watching the performance of political representatives. He said that too often men of high caliber who could exert a straightforward, intelligent influence on political activity sit idly by only to be forced into undesirable conditions affecting business and themselves.

CHEMICAL ENGINEERING TRAINING FILMS OFFERED

A list of chemical engineering educational training films has been made available by the Films Subcommittee of the Institute's Chemical Engineering Educational Projects Committee. Under the chairmanship of M. W. Bredekamp a 1954 supplementary section has been added to the 1953 list. The list with the supplement is available from the Institute's offices upon request.

Films on all phases of chemical engineering are included. A few of the topics covered are corrosion, fluid flow, heat transfer, materials handling, instrumentation, and material separation and mixing. The films are available to student chapters, local sections and other interested groups.

Institute members working on the program of compiling and recommending the lists were B. Williams, L. W. Gleekman, R. C. Kintner, A. Syverson, D. E. Holcolm, and C. C. Monrad.

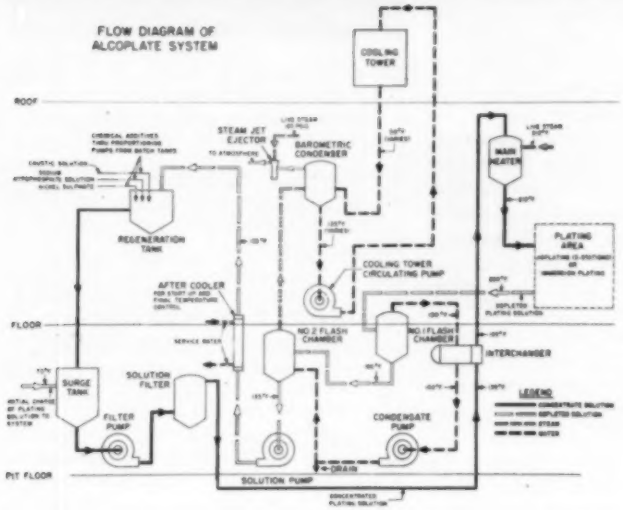
Lower cost protection against corrosion, increased equipment life of parts subject to hard wear and abrasion, and the salvage of parts that become unusable due to excessive wear are some of the advantages that are claimed for a new method of chemically coating nickel on low-cost base metals. The new process has been developed by the General American Transportation Co., Chicago, and licensed by them to both domestic and foreign interests. The process is called KANIGEN by GATX and ALCOPLATE by the American Locomotive Co., an American licensee. The advantages that can be realized from this new metal coating process appear so numerous that it is difficult to predict the impact of this process on chemical engineering design and economics.

The process allows the deposition of a uniform controlled thickness of nickel or cobalt on almost all metal and many nonmetallic surfaces of any size or shape. Its porosity in all practical thicknesses, which can be controlled within 1/-10,000th of an inch, is practically zero assuring protection of the base metal against chemical attack. The adhesion of the nickel plate is excellent, often stronger than the strength of the base metal, and its corrosion resistance is equal to and in some cases superior to wrought nickel. The hardness of the coating is approximately 48 Rockwell C and can be increased to 66 Rockwell C with heat treatment.

Some of the major applications presently using this coating technique are in the lining of tank cars by GATX and the internal coating of pipe and converters used in AEC gaseous transmission equipment, heat exchangers and other large vessels by ALCOA. The process can be used to coat the inside threads of valves or the insides of pumps with controlled thicknesses. It can be used to cover external portions of gears which may be located near corrosive atmosphere or may be used to completely encase a vessel such as a heat exchanger after it has been assembled, thus eliminating electrolytic corrosion due to the presence of a dissimilar metal junction.

These applications economically may benefit equipment economics. The corrosion protection of nickel can be achieved by coating a base metal or alloy with nickel via this process.

Repairing injured surfaces that leave susceptible areas exposed is easily accomplished with this process in the user's plant when necessary.



chemical nickel coating boon to process equipment

R. W. Glasheen
Associate Editor

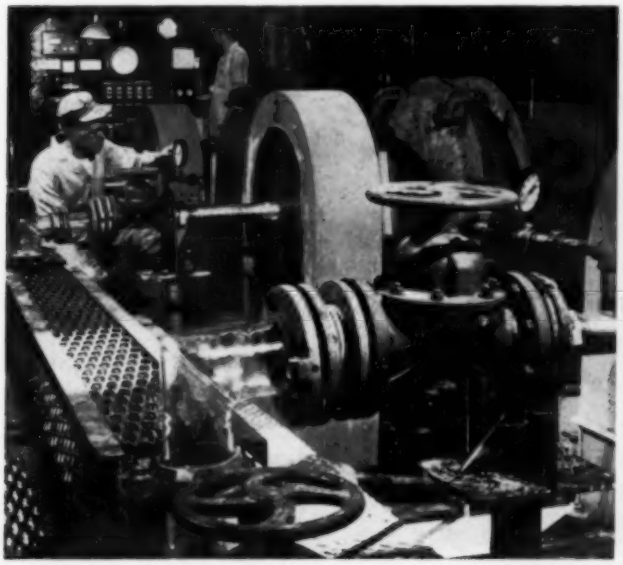
With this process to coat with nickel it is only necessary to flow the plating solution under proper control conditions onto the surface of the metal to be coated, and a non-porous, adhesive, hard nickel bond is formed. Regardless of the size or shape of the plated body there will be an even coat into every crack and crevice exposed.

The preplating treatment consists of an immersion of the material in hot alkali (180° F), a rinse in cold water, a pickling in hydrochloric acid, followed by a rinse in water and a second immersion in the alkali cleaner. These operations are substantially the same as performed in electroplating operations.

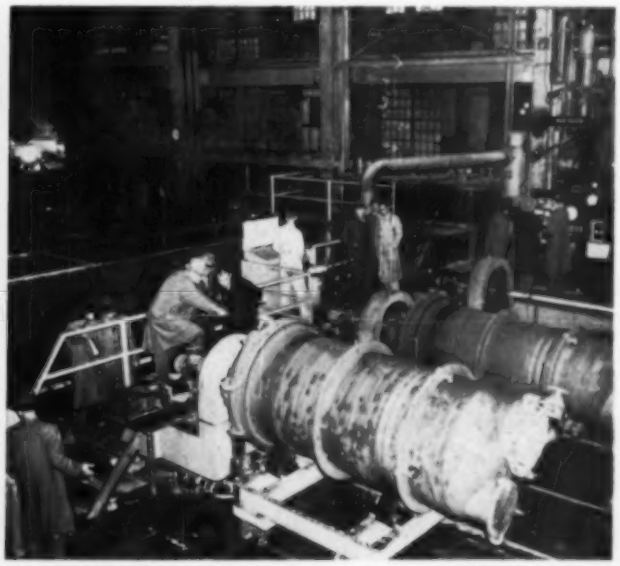
The plating solution is made up of nickel sulfate, sodium hypophosphite, and caustic. The solution is heated to a temperature of 215° F and then circulated through or over the work to be plated. Contact of the solution with the metal to be plated starts the reaction. This is called catalytic nickel generation since the metal surface contact acts as a catalyst to start the precipitation. The plating takes place chemically by the catalytic reduction of sodium hypophosphite at the elevated temperature. After passing over the plated surface the solution is returned to a regeneration tank where the solution is reconstructed to its proper analysis. pH is a factor that must be critically controlled. Lack of control will cause the solution to spontaneously deposit nickel on which the nickel in the solution will nucleate.

The post plating treatment consists of immersion in room temperature water followed by hot alkaline and final rinse water.

KANIGEN or ALCOPLATE has excellent corrosion resistance against neutral or alkaline solutions. Accelerated service tests by ALCO show uniformly excellent results against caustic, soaps, fats, alcohol, plastics, petroleum products, phenols, chlorinated solvents and water (including high humidity atmospheres). The plating shows excellent resistance to higher fatty acids such as oleic and stearic, or dilute sulfuric acid.



Close-up of glass piping connections to process vessels undergoing internal nickel coating.



View of ALCO shop showing large vessels being internally coated by the ALCOPLATE process. Vessels are not rotated during application of coating.

nuclear engineering division

The Nuclear Engineering and Science Congress sponsored by a committee of Engineers Joint Council will be held in Cleveland, Ohio, December 12-16, 1955, according to a decision announced by J. R. Dunning and D. L. Katz, chairmen respectively of the General and Program Committees of the Committee on Nuclear Engineering and Science EJC. Collaborating in the organization and sponsorship of this event will be the chemical, civil, electrical, metallurgical, mining, and water works engineers, plus the naval architects, the Society of Engineering Education, and the American Chemical Society. Other societies may complete arrangements shortly and announce plans for participation.

The A.I.Ch.E. Nuclear Engineering Division has completed arrangements for sponsoring an "Atoms for Peace" industrial exhibition which will be similar to the one held at Ann Arbor in June, 1954.

Authors interested in presenting papers under the sponsorship of the Nuclear Engineering Division of A.I.Ch.E. should contact Dr. W. K. Woods, Vice-Chairman of the Division, at General Electric Co., Richland, Wash.

MAJOR REVISION OF CLASSIFICATION UNDER WAY

It is understood that a major revision of rules for classification of nuclear information is under way in Washington, and will be announced shortly. Present indications are that all so-called "grey zone" material may be released. This will affect the preparation of papers for subsequent presentation and publication for the Nuclear Congress, and will affect greatly the availability of information for use by industry.

L.R.—D. L. Katz, J. J. Martin, W. K. Woods, R. P. Genereaux.

UN NUCLEAR MEETING AT GENEVA, SWITZERLAND, AUGUST, 1955

Word has reached us that the International Meeting on Nuclear Energy, sponsored by the UN, will be held in Geneva, Switzerland, during the first two weeks of August, 1955. The session on reactor technology (one of the principal sessions) will be closed, limited to official delegates numbering about 650. Because of the restricted attendance, consideration is being given by the EJC General, Program and Publications Committees to the possibility of inviting re-presentation of at least some of the papers given at Geneva by U. S. authors, to permit free discussion by those attending the Congress.

We regret to announce the death of Dr. S. S. Bhatnagar, a leading nuclear scientist of India, who headed the Indian Delegation at the Nuclear Engineering Congress at Ann Arbor in 1954.

—J. J. Martin
Secretary

TYLER RECEIVES OFFICE TESTIMONIAL

Left—S. L. Tyler, Mrs. Tyler, F. J. Van Antwerpen.

A surprise testimonial was given to Stephen L. Tyler, retiring secretary of the Institute, by the members of the Institute office staff on December 3rd in the Advertisers Club in New York. Steve was presented with a gift of a silver tray on which was inscribed "To Stephen L. Tyler, Secretary, A.I.Ch.E., from your friends at the office, December 3, 1954."

1955 Meetings on Nuclear Technology

April 27-29, Los Angeles, Calif.; 1955 Conference on Nuclear Engineering, University of California.

August 1-13, Geneva, Switzerland; UN International Meeting on Nuclear Energy. By invitation.

September 25-28, Lake Placid, N. Y.; Nuclear Engineering Division sponsoring symposium on "Atom Profits" at A.I.Ch.E. resort meeting.

December 12-16, Cleveland, Ohio; Nuclear Engineering & Science Congress, sponsored by EJC Committee, together with "Atoms for Peace" industrial exhibition sponsored by A.I.Ch.E.

We have also been informed that the American Nuclear Society is planning its first technical and organizing meeting in June.

process equipment

applications engineering

Substitution of titanium for stainless steel in certain highly corrosive conditions impractical with most metals has resulted in longer operating life of equipment according to Rem-Cru Inc., Midland, Pa. An example is a giant valve supplied by Minneapolis Honeywell being used to handle corrosive fluids flowing at high velocities and high pressures by a leading chemical manufacturer.

The giant titanium valve bodies are machined from Rem-Cru A-70 titanium forgings weighing 320 lb. each. A-70 bar stock is used for the trim. The valve resists a corrosive solution which has an inlet pressure of 3000 lb./sq.in. with a 2700 lb./sq.in. pressure drop. The valve port is 1 in. in diameter.

A stainless steel valve used in the same application lost control after 70 hours of service. So far the titanium valve has operated 1680 hours without overhauling, an incraese of 24 times.

Titanium's combination of unique corrosion resistance and high strength has made this design possible. With ample supply of titanium now available for defense applications, chemical engineers are working with new processes involving temperatures and pressures which were formerly out of the question because of the limitations of the available materials.

A.I.Ch.E. News of the Field
FROM LOCAL SECTIONS

Boston. Farming of the seas—the activities and projects of the Oceanographic Institution in Woods Hole, Mass., were told to the Icthyologists on November 19 in Boston. Mr. J. Hahn spoke on "What Every 'Fish' Should Know About the Sea."

Mr. Hahn noted the origin of the Oceanographic Institution in 1925 with a $2 million grant from the Rockefeller Foundation for the purpose of accumulating basic data about the sea. In 1940 the operations were expanded under the necessities of the War Department from a summer operation handled by University professors, to that made possible by a full time staff. Presently, field work is conducted in three sea-going vessels and a PBY seaplane. Among the ships is the famed 'Atlantis' designed and built in 1930.

Several of the Institution techniques were invaluable to the war effort. Submarine sound techniques developed into sonar. Anti-fouling paints saved 10% of the wartime fuel bill. Available knowledge of the all important influence of the ocean on weather was a major contribution to Naval strategy.

Mr. Hahn described an oceanographic scientist as one possessed of a consuming interest for and compatibility with seafaring, since data must be collected at the source under all conditions of climate and weather with Spartan disregard for ills and annoyances. Data gathering cruises usually extend over four-month periods.

Oceanography, for the present, is largely a matter of observation and not very subject to theory, according to Mr. Hahn. The early predominance of biology has given way to physics and a mass of electronic measuring devices. Present biological studies are directed toward phosphate - nitrate - life balance and the distribution of the known species of fishes. Some of these studies are of direct benefit to the fisheries.

Another major activity is submarine geology. Many interesting devices are used for exploring the sea bottom, and it is now possible to obtain submarine borings up to 60 feet in depth. Most observations, however, are sound phenomena employing depth charges of many varieties.

Mr. Hahn described a new electromagnetic induction device called the "Geek," used in oceanography for the measurement of ocean circulation. This device gives acceptable precision to a previously difficult measurement. The simple approach of measurement by anchoring in deep water to determine

flow rates proved to be a difficult experience for even the hardiest of mariners. Temperature-pressure analyses proved to be inadequate.

The importance to our national welfare of oceanographic activities was stressed, and the recognition that the major world contributions to this field were made by the United States was credited. Mr. Hahn warned that other nations are putting more effort and expense into this activity than is the U.S.A.

—A. G. Smith

Knoxville, Tennessee. "Man is one of the most radiosensitive of animals" according to A. C. Upton, Chief of Pathology and Physiology Section, Oak Ridge National Laboratory, speaking before the Knoxville-Oak Ridge Section in October. In his talk on "Radiation Injury in Man" Mr. Upton said that many of the physiological reactions induced by gamma and neutron irradiation have been observed to be irreversible and develop gradually appearing many months after exposure.

Ionizing radiations are believed to injure living matter primarily by producing ions as they are absorbed, the amount of energy being related to the amount and distribution of ionization. In general, the degree of damage is also proportional to the rate of delivery of the radiation. The biological effects of the various types of radiations differ quantitatively but apparently not qualitatively; for example, in causing most types of injury, neutrons are more effective than gamma rays. Since x-rays and gamma rays penetrate tissue much more rapidly than particle radiations, they constitute a greater external hazard than alpha or beta particles; however, internally deposited isotopes emitting these particles may be highly damaging because of the high ionizing density.

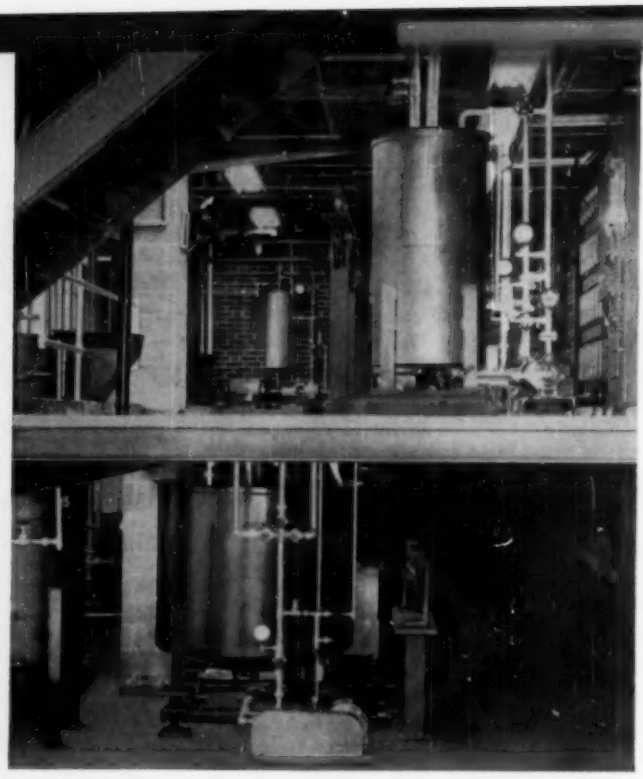
Biological systems vary widely in radiosensitivity: the lethal dose for humans being approximately 400-500 Roentgens. Likewise, the cells within the body are of varying radiosensitivity with the rapidly dividing cells being, in general, most sensitive. Some of these organs of rapid cell formation are blood forming tissues, the gonads, the lining of the gastro-intestinal tract, and the skin. Symptoms of damage to these organs manifest themselves in the lowering of the blood count, susceptibility to hemorrhage and infection, nausea, fever, inflamation and ulceration of the mouth and intestinal tract, and epilation. These effects are maximal within the first few weeks after irradiation, recovery occurring during the second or third months. Developing concomittantly and of longer duration are the disturbances of gonadal

(*Continued on page* 68)

eral reagent compositions and operation

sharples opens demonstration refinery for vegetable oils

A full scale demonstration oil refinery is being used to determine the optimum process conditions for the production of vegetable oils and the most efficient use of process equipment under typical operating conditions by Sharples Corporation at their Philadelphia works. Results of investigations are being passed on to commercial refiners to improve the economics of the billion dollar per year vegetable oil refining industry. The refinery is versatile being able to process a tank car (60,000 lb.) per day by any one of the five different processes currently used in production of such products as salad oil, shortening and oleomargarine. Typical production refineries range from ½ to 4 tank cars of oil per day, in capacity.



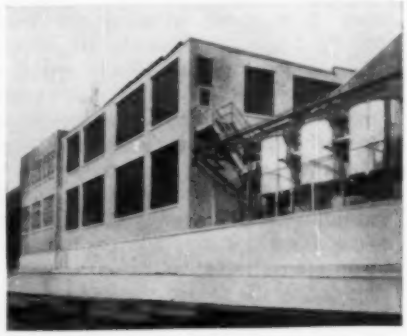
Partial end view of 3-story refinery.

"The day of the vegetable oil pilot plant is gone. For demonstration and research and for economic studies of various processes only full scale production runs under typical refinery conditions can provide the facts the industry needs for more profitable operation," according to F. W. Stakelbeck, Sharples executive vice-president. Sharples is said to have found out through experience that the results obtained from a pilot plant, which this new refinery replaces at Sharples, does not give reliable scale up factors and does not sufficiently reproduce actual production conditions which will enable process improvement.

The continuous refining to vegetable oils is divided into five major processes. These differ in the reagents that are used for precipitation and the subsequent physical operations used to separate the precipitated constituents. The five major reagents used are caustic, soda ash, modified soda ash, ammonia and modified caustic. The addition of one of these materials precipitates the gums, neutralizes the fatty acids and reduces the color of the oil. Depending upon which oil is being processed and the reagent used, a combination of dehydrations, mixings, heatings and centrifuges are required.

The determination of the optimum process conditions entails a trial of sev-

	Crude Oil ↓	Caustic	Soda Ash	Modified Soda Ash	Ammonia	Modified Caustic
Weigh	Weighing	•	•	•	•	•
Primary refining	Volumetric proportioning		•			
	Mixing		•			
	Heating		•			
	Dehydrating		•			
	Volumetric proportioning	•	•	•	•	•
	Mixing	•	•	•	•	•
	Heating	•	•	•	•	•
	Centrifuging	•	•	•	•	•
Color refining	Cooling		•	•	•	•
	Volumetric proportioning		•	•	•	•
	Mixing		•	•	•	•
	Heating		•	•	•	•
	Centrifuging		•	•	•	•
1st water wash	Mixing & heating	•	•	•	•	•
	Centrifuge	•	•	•	•	•
2nd water wash	Mixing & heating	•	•	•	•	•
	Centrifuge	•	•	•	•	•
Dry	Vacuum drying	•	•	•	•	•
Weigh	Weighing	•	•	•	•	•
	↓ Refined oil					

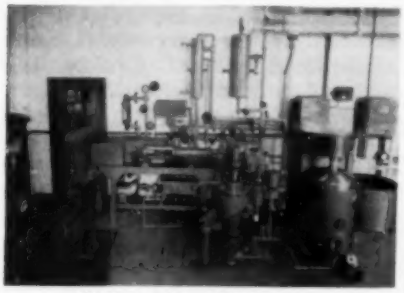


Demonstration plant exterior.

eral reagent compositions and operation cycles. Normally a commercial oil refiner does not have available the facilities necessary to experiment with all of the processes and equipment modifications.

With the new Sharples refinery all the processes and variations with equipment can be run on any oil to determine whether or not information gained of value in one type of oil refining may be used with success in modifying other oil refining processes.

One of the problems involved in these refining operations is the unwanted precipitation of neutral oils that are hydrolyzed by the presence of water that is present in the caustic reagent. The longer the time of contact of this water with the neutral oils the greater will be the loss of usable or saleable oils that are converted.



Mixing and centrifuging units.

The use of the centrifuge results in accelerated separations which minimize the time of contact of oil and moisture. This results in a higher recovery of useable oil and thus a greater economy. The higher the gravitational force achieved in the centrifuge the greater is the compression of the unwanted precipitate. This results in oil saving due to less entrainment of oil. Gravitational forces achieved in modern Sharples machines go as high as 16,000 g's, as compared with 13,000 g's formerly considered efficient in industrial practice. The proper choice of centrifuge most economical for a particular operation has been correlated by process studies by Sharples. Previously many installations used the same type of centrifuge regardless of the operation desired.

(*Continued on page 74*)

Reagent and stock tanks on scales.

News of the Field
FROM LOCAL SECTIONS

(*Continued from page 65*)

function, including permanent genetic damage which is hereditary.

The lens of the eye is highly sensitive, especially to neutron irradiation. Radiation induced cataract of the lens has been observed in Japanese atomic bomb victims and in cyclotron workers. This injury occurs with sublethal doses, is irreversible, and develops gradually appearing many months after irradiation.

—R. P. MILFORD

West Virginia. "Forecasting for the Chemical Industry" was the topic discussed by R. H. Ewell, of the National Science Foundation, before 136 members and guests of the Charleston Section on November 16. Dr. Ewell stressed the important part that intelligent forecasting plays in making business decisions and pointed out that a great majority of chemical forecasts in the past have been too conservative resulting in lost money due to missed opportunities.

In the past 25 years, chemical production has increased at the rate of 10% per year, compared to about 3% per year for the average of all other industries. The use of intuitional or "hunch" forecasting of markets and growth is being replaced by more objective methods based on either the techniques of projection of past history or of correlation.

Projection of past history is reliable only for the sum of a group of competing materials-building materials, plastics or combined soap and synthetic detergents. Many growth trends can be closely correlated by the Gompertz equation, $Y = \log K + ab^x$. For the best appraisal of a particular market, both the macroscopic (overall) and microscopic (detailed) aspects of the uses for particular chemical or group must be examined. A history of 18 to 24 years is necessary to compute a satisfactory Gompertz curve.

The correlation approach compares closely allied products such as rubber and petroleum, fertilizer and ammonia, or rayon and carbon disulfide. Predictions of this type are, of course, dependent upon factors affecting the prediction for the primary commodity.

Dr. Ewell emphasized that the methods he described are for long-range forecasting and are worthless for short-term predictions.

—R. W. TIMMERMAN

Tennessee. "The time for action in the search for new energy sources has arrived." Dr. William Arnold in a talk "Population and Energy" to the December 10 meeting of the Knoxville-Oak Ridge Section reviewed the book "Energy in the Future" by Palmer C. Putnam. Mr. Putnam bases his opinion on the growth in world population, the increased rate of energy consumption and the estimated reserves of fossil fuels.

Dr. Arnold, Biology Division, Oak Ridge National Laboratory, said that three of the processes where future low cost energy sources will be beneficial are the design of a factory powered by atomic energy for the production of starch or sugar, a process for the large scale conversion of sub-marginal soils to productive farm land, and an economically feasible process for producing salt-free water from the ocean.

—R. P. Milford

Central Ohio. The popular speech, "Atomic Energy, Weapon for Peace," which has been enthusiastically received by over 700 audiences and a half a million people, was presented by Dr. H. N. Alyea, Professor of Chemistry, Princeton, at the recent November 16 meeting of the Central Ohio Section. To dramatize his presentation Dr. Alyea performed chemical experiments before the group.

During his talk he traced the growth of ideas that led to the atom bomb from the work of the alchemists, through the discovery of radioactivity, the isolation of radium, and the concept of the nuclear atom. He contrasted the action of ordinary high explosives with those of nuclear fission and discussed and analyzed the H-Bomb.

In dicussing the nuclear reactor he outlined the many elements produced in it and told what is being done with radioactive isotopes.

—E. E. Smith

New York. "Engineering Aptitude: Fact and Fallacy" was the subject of a talk before the Rochester Section on November 10. Dr. L. Lipsett, Director of the Counselling Center, Rochester Institute of Technology, described the abilities, aptitudes and achievements that engineers have in common. He discussed some of the common fallacies concerning the degree of predictability in vocational guidance and personnel placement work. It was announced at the meeting that the local section has reached 262 members.

—J. A. Mason

News of the Field

FROM LOCAL SECTIONS

Washington, D. C. For the current year the officers of The Chemical Engineers Club of Washington, National Capitol Section will be Chairman, M. T. Bennett; Vice-Chairman, A. C. Scurlock; Treasurer, H. B. Peterson; Secretary, D. M. Kiefer; Past Chairman, D. O. Myatt. Chairmen of the Club's committees are: Programs, J. L. Gillman, Jr.; Arrangements, F. C. Moesel; Public Relations, P. R. Hopper; Membership, P. S. Forsyth. —D. M. KIEFER

Southern California. Highlights of his foreign assignment as Chemical Production Specialist for the Mutual Security Agency were reported by R. E. Vivian, Dean of the College of Engineering at the University of Southern California, before the Southern California Section on November 16. In his three month tour of the far east, Dr. Vivian was consultant for the restoration and operation of chemical plants producing smokeless powder, explosives, and related chemicals in such areas as Formosa, Thailand and Malaya. Supplementing his talk were slides showing the condition of the foreign chemical and explosives industries. —F. G. SAWYER

News of the Field
FROM LOCAL SECTIONS

East Tennessee. The progress of an A.I.Ch.E. research project on predicting efficiencies in vapor-liquid equipment was the subject of a talk by E. M. Schoenborn, Chemical Engineering Dept. Head North Carolina State, presented to the East Tennessee Section on October 14. The work is being carried on at three Universities.

At North Carolina State the work is concerned with the study of the effect of physical properties on the efficiency of a distillation system. The work at the University of Delaware is concerned with the effect of operating characteristics and tray design on efficiency, and the work at the University of Michigan is concerned with predicting efficiencies in absorption systems. Work on the project has been underway for about a year and Dr. Schoenborn speculates that considerably more time will be required before the project can be finished.

A theoretical treatment of the techniques of particle surface measurement was presented by J. M. Dalla Valle, Chemical Engineering Department, Georgia Tech, to the East Tennessee Section on November 10. He briefly described the mathematics relating mean particle size to surface measurement and the techniques of pressure drop, gas absorption, conductivity, and mono molecular films for measuring particle surfaces on particles less than 10 microns in size.

An election of officers was conducted at the December 8 meeting of the East Tennessee Section.

Those elected for the 1955 year were Chairman, A. H. Scott; Vice-Chairman, T. Reid; Secretary-Treasurer, P. C. Underwood; Director, R. Petrey.

The functions of a trust department and the methods of handling estates were described to the meeting by E. E. Russ, Trust Officer of the First National Bank of Kingsport. Mr. Russ told how an estate is handled if there is no will and the advantages of establishing a plan before death for the execution of one's estate.

A film was shown describing the continuous Turbo drier, a product of the Wyssmont Co.

—M. L. GERNERT

West Texas. The theoretical and practical aspects involved in selecting suitable devices for controlling a process was the text of a talk on "Process Systems Engineering" given to the Sabine Area Section in Beaumont, Texas, at their November 10 meeting. Approximately 75 members heard the talk by D. Campbell of M.I.T.

—W. E. NORRIS

CANDIDATES FOR MEMBERSHIP IN A. I. Ch. E.

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on admissions.

These names are listed in accordance with Article III, Section 8, of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Members will receive careful consideration if received before February 15, 1955, at the office of the Secretary, A.I.Ch.E., 25 West 45th Street, New York 36, N. Y.

Member

Arnold, D. S., *Hamilton, Ohio*
Belmore, Frederick M., *Carle Place, L. I., N. Y.*
Bossen, Roger G., *Cuyahoga Falls, Ohio*
Bozich, Samuel, *Baytown, Tex.*
Cumming, John T., *Cleveland, Ohio*
Eikstrems, Arvids J., *New York, N. Y.*
Flynn, James J., *Philadelphia, Pa.*
Grauten, Arthur H., *Baltimore, Md.*
Harp, W. M., *Baytown, Tex.*
Henderson, James B., *New York, N. Y.*
Horine, C. L., *China Lake, Calif.*
Kranich, Wilmer L., *Worcester, Mass.*
Kronseder, John G., *Chicago, Ill.*
Louis, Jack R., *Charleston, W. Va.*
Mantz, John W., *Cleveland, Ohio*
McBride, Guy T., Jr., *Houston, Tex.*
McGriff, Stuart Gray, *Callery, Pa.*
Milligan, Robert T., *Emeryville, Calif.*
Moyer, W. C., *Port Arthur, Tex.*
Ramsey, Knowles, *Elkton, Va.*
Ray, Robert S., *Fullerton, Calif.*
Scovic, James M., *Midland, Mich.*
Trombly, Arthur J., *Wilmington, Del.*
Wheeler, William W., *Pasadena, Tex.*
Zytkus, Eugene H., *Waynesboro, Va.*

Associate

Arens, James L., *Phillips, Tex.*
Barbor, Richard P., *Marcus Hook, Pa.*
Baumgarten, P. K., *Newark, Del.*
Bedel, Donald Paul, *Notre Dame, Ind.*
Bellew, R. E., *Midland, Mich.*
Bishop, George A., *La Crosse, Wis.*
Borsuk, Edward John, *Brookfield, Ill.*
Castner, Foster J., *New Brunswick, N. J.*
Chadwick, F. E., *Binghamton, N. Y.*
Cocherell, Arthur L., *North Madison, Ohio*
Dalrymple, W. R., *Aldershot, Ont., Can.*
Daniel, J. M., Jr., *Richmond, Va.*
Davis, Robert I., *Corpus Christi, Tex.*
Denning, W. G., *Baytown, Tex.*
Dickson, Joe C., *Baytown, Tex.*
Doar, Le Roy H., Jr., *Wilmington, Del.*
Enyedy, Gustav, Jr., *Cleveland Heights, Ohio*
Goodgame, Thomas H., *Ipswich, Mass.*
Grady, Robert B., *Baton Rouge, La.*
Griffin, David F., *Baytown, Tex.*
Griffin, Donald E., *Idaho Falls, Idaho*
Guthrie, D. L., *Baytown, Tex.*
Haydon, William M., *Charleston, W. Va.*
Hoffman, James P., *Norwood, Pa.*
Holbrook, Franklin M., *Houston, Tex.*
Hutchings, William Halstead, *La Habra, Calif.*
Ingham, Rodney R., *Augusta, Ga.*
Julian, F. M., *San Francisco, Calif.*
Kapner, Robert S., *Brooklyn, N. Y.*
Karay, Alexander X., *Zeeland, Mich.*
Kaufman, Rolf, *Army Chemical Center, Md.*
Kelley, Robert E., *Baytown, Tex.*
Klassen, Hugh A., *Oak Ridge, Tenn.*
Lewish, William T., *Springfield, N. J.*
Lord, Richard L. M., *Montreal, Que., Can.*
Lowell, Philip S., *Port Neches, Tex.*
Luckow, Lloyd H., *Houston, Tex.*
McKinnie, Curtis J., *Camas, Wash.*
Mihailoff, Vadim V., *Richmond, Calif.*
Miller, David, *Lemont, Ill.*
Miller, Loren N., *Wilmington, Del.*
Mills, Albert D., *Minneapolis, Minn.*
Mittman, Daniel, *Nitro, W. Va.*
Noble, Ronald E., *Pottstown, Pa.*

(Continued on page 75)

A.I.Ch.E. News of the Field

FROM LOCAL SECTIONS

Ohio. A trip through an equipment fabrication plant constituted the October 14 meeting of the Akron Section. Over 100 members visited the Pfaudler Co. in Elyria where they observed the manufacture of alloy and glass lined equipment. Much of the equipment fabricated is their standard line of heat exchangers and vessels up to 1000 gallon capacity. Special linings are used on equipment that are subject to severe or special corrosive conditions, polymer contamination, and sanitation requirements.

Many of the operations performed in the alloy and glass lining fabrications are similar. Glass lining operations include the application to the base metal of the glass—frit, firing and drying processes. Other operations observed were roll trimming and edge preparation, welding, fitting and flanging.

The outcome of several meetings organized for the advancement of the professional standards of chemical engineers was told to the Akron Section by R. P. Dinsmore, a director of the Institute, at their November 11 meeting. Mr. Dinsmore gave a report of activities in Council and described the Institute's new office headquarters.

The featured speaker of the evening, Mr. E. Reineck, Asst. Sales Mgr., Quaker Oats Co., talked about the uses of furans-chemicals from corn. One of the products mentioned was furfural.

It may be some time before chemical engineers may use titanium to advantage in chemical processing equipment. In a talk given to the December 9 meeting of the Akron section, W. W. Scheel Titanium development metallurgist of Republic Steel in Canton, said that with the present $15 to $20 per pound and with present Government demands it may not yet be economical to take advantage of the high heat and corrosion resistant properties of this wonder metal.

At this meeting members were elected to serve as officers for 1955. They are Chairman, W. Otto; Vice-Chairman, H. Baker; Secretary, T. H. Rogers; Treasurer, W. Wilson. —H. L. NICHOLSON

Idaho. "Corrosion in Action" was the subject of a film shown to the Idaho Chemical Engineering Society at its fourth meeting on November 16, held in Idaho Falls, Idaho. R. S. MacCormack, Corrosion Specialist for the atomic energy division of the Phillips Petroleum Co., discussed the film.

The society, which has been organized for eventual local section status, has for its officers: Chairman, C. E. Stoops; Secretary, G. E. Lohse; Treasurer, L. Chajson. —C. E. STOOPS

News of the Field
FROM LOCAL SECTIONS

Savannah River, Georgia. A unanimous acceptance of Institute by-laws was the result of a vote by the Savannah River Chemical Engineer's Club at their December 9 meeting. The club is currently seeking approval of council for local section status.

New officers were elected for the 1955 year. They are Chairman, J. B. Roberts; Vice-Chairman, W. P. Bebbington; Secretary, J. R. Oldenburg; Treasurer, B. L. Baker; Director, L. C. Peery; Director, J. W. Morris.

A stimulating talk on "Creative Engineering and Research" was presented by C. M. Cooper, Director of Dupont's Engineering Research Laboratory, Wilmington, Delaware.

—R. W. HINTERLEITER

Northeastern New York. The annual election of officers for the Northeastern New York Section was held on December 1st. The results of the election are: Chairman, R. Heitzman; Vice-Chairman, W. N. Frank; Secretary, K. S. Watson; Treasurer, T. J. Cashman.

—A. C. SHAFER, JR.

SHARPLES PLANT

(*Continued from page 67*)

One of the unique features of this new refinery is the placement of weigh tanks, metering and other control devices, and an elaborate network of piping throughout the system which permits extreme flexibility plus accurate control over every element of the crude oil which is refined or removed as a by-product.

It has only been during the last ten years that processes other than that using caustic reagents have been accepted for wide use. In earlier stages of refining history about 50% of the neutral oil was lost due to such conditions as hydrolysis of or entrainment. Recent improvements described above have resulted in increasing yields until only about 10% is now lost. New chemical approaches as well as machinery advances are being studied with the objective of recovering as much as possible of this 10%. Economically, this 10% represents to the industry, a sizeable sum of money.

The accompanying flow chart gives an indication of the versatility of the plant. The five major processes shown horizontally across the top of the chart are normally subjected to the corresponding sequence of operations shown vertically. The chart shows the number of operations which can be cut in or bypassed at will to create process variations.

CANDIDATES

(*Continued from page 72*)

Payne, Robert E., *Baytown, Tex.*
Pierson, Russell, *Argo, Ill.*
Polubinsky, Norman P., *St. Paul, Minn.*
Reilly, Robert J., *Wilmington, Del.*
Riddle, Joe A., III, *La Marque, Tex.*
Rubini, Salvatore, V., *Wilmington, Del.*
Ryan, Gerald W., *Des Plaines, Ill.*
Schnelzer, John A., *Frostburg, Md.*
Schwab, Richard F., *New York, N. Y.*
Shade, Ray W., *Schenectady, N. Y.*
Slaughter, John M., *Charleston, W. Va.*
Stevens, Wayne E., *Baytown, Tex.*
Sweat, Robert H., *Kingsport, Tenn.*
Tracy, Ward G., *Londonville, N. Y.*
Wall, Robert H., Jr., *Midland, Mich.*
Watkins, Ronald G., *Calgary, Alberta, Can.*
Wheeler, R. Phillip, *Ponca City, Okla.*
Willingham, William E., *Downey, Calif.*
Wilson, John M., *Bergenfield, N. J.*
Woehrle, R. E., *Trafford, Pa.*
Wray, M. Haltom, *Deer Park, Tex.*
Yanne, Edward D., *Springfield, Mass.*

Affiliate

Rosinski, Edward J., *Sewell, N. J.*

MILITARY ENGINEERS HOLD INDUSTRIAL CONFERENCE

What will be the demand on available engineering personnel by the government and industry in case of a national emergency? How and where should an allocation of personnel take place? These will be the types of questions put before a panel at the Military Industrial Conference of the Society of Military Engineers to be held on February 10 and 11th at the Conrad Hilton Hotel, Chicago, Illinois. The conference designed to discuss the engineering manpower situation in times of emergency will have in addition to the panel discussion a series of talks on the subject by prominent industrial, academic and government people.

ECPD ACCREDITS ChE AT FENN

The chemical engineering program at Fenn College in Cleveland, Ohio, has, upon recommendation of the A.I.Ch.E., been accredited by the Engineers Council for Professional Development. Following an inspection of the program and facilities last year by the Institute, both day and evening curricula of the College were approved. Chairman of the Dept. of Chemical Engineering at Fenn is Dr. A. J. Teller, a member of the Institute.

FUTURE MEETINGS and Symposia of the Institute

MEETINGS **SYMPOSIA**

■ LOUISVILLE, KY.

March 20-23, 1955. Kentucky Hotel.

TECHNICAL PROGRAM CHAIRMAN: R. M. Reed, Tech. Dir., Gas Proc. Div., The Girdler Corp., Louisville 1, Ky.

Heat Transfer—Joint with A.S.M.E.

CHAIRMAN: R. L. Pigford, Div. of Chem. Eng., Univ. of Delaware, Newark, Del.

Propellant Power

CHAIRMAN: R. A. Cooly, Explosives Div., Olin Mathieson Chemical Corp., East Alton, Illinois.

Industrial Relations

CHAIRMAN: Guy B. Arthur Jr., Industrial Consultant, Toccoa, Ga.

Centrifugation

CHAIRMAN: J. O. Maloney, Chairman, Dept. Chem. Eng., Univ. of Kansas, Lawrence, Kan.

Solvent Extraction

CHAIRMAN: Dr. R. B. Beckman, Dept. Chem. Eng., Carnegie Inst. of Tech., Schenley Park, Pittsburgh 13, Pa.

Deadline Past

■ HOUSTON, TEXAS

May 1-4, 1955. Shamrock Hotel.

TECHNICAL PROGRAM CHAIRMAN: J. L. Franklin, Res. Assoc., Humble Oil & Refining Co., P. O. Box 1111, Baytown, Texas.

Nucleation Processes

CHAIRMAN: D. W. Oakley, Plant Mgr., Metal & Thermit Corp., 1 Union St., Carteret, N. J.

Flow of Fluids Through Porous Media

CHAIRMAN: H. Dayton Wilde, Mgr. Res. Div., Humble Oil & Ref. Co., Box 2180, Houston 1, Tex.

Extractive and Azeotropic Distillation

CHAIRMAN: Dr. D. E. Holcomb, Dean of Eng., Texas Technological College, Lubbock, Tex.

The Chemical Engineering Curriculum

CHAIRMAN: Dr. J. W. Mason, Dean of Eng., Georgia Inst. of Tech., Atlanta, Ga.

Differences in Chemical Engineering Theory

CHAIRMAN: Dr. F. A. Landee, Dow Chemical Co,. Midland, Michigan.

Deadline Past

■ LAKE PLACID, N. Y.

Sept. 25-28, 1955. Lake Placid Club.

A meeting devoted to the problems of interest to top management.

TECHNICAL PROGRAM CHAIRMAN: L. J. Coulthurst, Mgr. Proc. Engr., Foster Wheeler Corp., 165 Broadway, New York 6, N. Y.

Chemical Engineering Organizations

CHAIRMAN: J. F. Thornton, Pres., The Lummus Co., 385 Madison Ave., New York 17, N. Y.

Growth of the Oil & Chemical Industry by Integration

CHAIRMAN: Mr. F. M. Simpson, Petroleum Chemicals Inc., 54 Wall St., New York 5, N. Y.

Deadline—May 25, 1955

Atom Profits

A symposium to be sponsored by the Nuclear Engineering Division.

NOTE—No general papers

MEETINGS **SYMPOSIA**

■ ANNUAL—DETROIT, MICH.

Nov. 27-30, 1955. Statler Hotel.

TECHNICAL PROGRAM CHAIRMAN: T. J. Carron, Supervisor, Chem. Eng. Section, Ethyl Corp., Res. Labs., 1600 West Eight Mile Road, Detroit 20, Mich.

Photochemical Processes

CHAIRMAN: Prof. J. J. Martin, Dept. Chem. Eng., Univ. of Michigan, Ann Arbor, Mich.

Biochemical Engineering

CHAIRMAN: Dr. H. O. Halvorsen, Dept. of Bacteriology, Univ. of Illinois, 362 Noyes Lab. of Chem., Urbana, Illinois.

Technical Societies Cooperation with Chemical Engineering Industries

CHAIRMAN: Prof. J. B. Phillips, Dept. Chem. Eng., Phys. Sciences Centre, McGill Univ., Montreal 2, Canada.

Bubble Mechanics

CHAIRMAN: Prof. R. C. Kintner, Dept. Chem. Eng., Ill. Inst. of Tech., 3300 Federal St., Chicago 16, Ill.

Deadline—July 27, 1955

■ LOS ANGELES, CALIF.

Feb. 26-29, 1956. Statler Hotel.

TECHNICAL PROGRAM CHAIRMAN: T. Weaver, Proc. Eng., The Fluor Corp., Ltd., Box 7030, East L. A. Station, Los Angeles 22, Calif.

Deadline—Oct. 26, 1955

■ ANNUAL—BOSTON, MASS.

Dec. 9-12, 1956. Hotel Statler.

TECHNICAL PROGRAM CHAIRMAN: W. C. Rousseau, Proc. & Sales Eng., Badger Mfg. Co., 230 Bent St., Cambridge 41, Mass.

Deadline—August 9, 1956

UNSCHEDULED

Extraction of Hydrocarbons for Chemical Use from Pipeline Gases

CHAIRMAN: E. E. Frye, J. F. Pritchard & Co., 210 W. 10th, Kansas City 5, Mo.

Fundamental Mechanisms in Boiling Cavitation and Condensation

CHAIRMAN: R. R. Hughes, Shell Development Co., Emeryville, Calif.

Engineers Joint Council Nuclear Engineering and Science Congress will be held in Cleveland, Ohio, on December 12-16, 1955.

The A.I.Ch.E. tentatively plans to sponsor papers on the following: liquid metals, heat transfer, radiation, and sterilization, and chemical manufacture, preparation of radio active sources, processing of spent fuels and temperature coefficient for reactors. A.I.Ch.E. representative—Dr. W. K. Woods, Vice-Chairman, Nucl. Eng. Div., General Electric Co., Richland, Wash.

AUTHOR INFORMATION

Submitting Papers

Members and nonmembers of the A.I.Ch.E. who wish to present papers at scheduled meetings of the Institute should follow the following procedure.

First, write to the Secretary of the A.I.Ch.E. Mr. F. J. Van Antwerpen, American Institute of Chemisal Engineers, 25 West 45th Street, New York, requesting three copies of the form "Proposal to Present a Paper Before the American Institute of Chemical Engineers." Complete these forms and send one copy to the Technical Program Chairman of the meeting for which the paper is intended, one copy to the Assistant Chairman of the A.I.Ch.E., Program Committee, address at the bottom of this page, and one copy to the Editor of Chemical Engineering Progress, Mr. J. B. Mellecker, 25 West 45th Street, New York.

If you wish to present the paper at a particular symposium, request 4 copies of the proposal sending a copy to the Chairman of the symposium.

Before Writing the Paper

Before beginning to write your paper you should obtain from the meeting Chairman, or from the office of the Secretary of the A.I.Ch.E., at 25 West 45th Street, New York, a copy of the A.I.Ch.E. Guide which covers the essentials required for submission of papers to the A.I.Ch.E. or its magazines.

Copies of Manuscript

Five copies of each manuscript must be prepared. For meetings, one should be sent to the Chairman of the symposium, and one to the Technical Program Chairman of the meeting at which the symposium is scheduled. If no symposium is involved, the two copies should be sent to the Technical Program Chairman. The other copies should be sent to the Editor's office. All manuscripts submitted to the A.I.Ch.E. Editor are automatically considered for C.E.P., the A.I.Ch.E. Journal, and the Symposium Series. Presentation at a meeting is no guarantee that manuscripts will be accepted.

Chairman, A.I.Ch.E. Program Committee
George Armistead, Jr., George Armistead & Co.,
1200 18th St., N.W., Washington, D. C.

Assistant Chairman
L. J. Coulthrust, Foster Wheeler Corp.
165 Broadway, New York 6, N. Y.

PEOPLE

SHELL BUILDS ANOTHER UOP UNIT

A new 16,000 B/SD UOP Platforming unit built for the Shell Oil Co.'s refinery at Wood River, Ill. has been recently put on-stream. This is the third UOP Platformer to be put in operation by Shell.

The new unit is processing naphtha derived from mixed crudes which boil in the range of 190 to 360° F. Operating for the production of motor fuel blending material only, the unit is producing 95 leaded octane Platformate.

Two other units recently put in operation are a 5,000 B/SD Platformer at Martinez, Calif. and a 16,000 bbl./day unit at Houston, Texas.

Universal Oil Products Company designed, engineered and licensed the Platforming unit with Procon Incorporated acting as contractor.

CLAD METALS STUDIED FOR TEMPERATURE STRESS

The stress reactions of clad metals at high temperatures will be determined during an extensive research program initiated by the Lukens Steel Co., Coatesville, Pa. Differences in thermal expansion of the joined metals, their yield strengths and possible effects on fatigue life under service conditions up to 1000° F. will be determined to aid in the design and stress evaluation for full-scale clad metal pressure vessels operating at high temperatures.

Initially, the program will be concentrated on the physical properties of stainless clad steel (18-8 type). This particular clad steel was selected because of the large difference in physical properties of the components—stainless and carbon steel.

the chemical engineer in marketing

John A. Field assumes responsibilities of vice-president of Carbide and Carbon Chemicals Company, a Division of Union Carbide and Carbon Corporation.

Mr. Field will work primarily with sales development and related activities including the company's fellowships at Mellon Institute, Pittsburgh.

After his graduation in 1935 from Yale University with a degree in chemistry, Mr. Field studied at Oxford University on a Henry Fellowship. He joined Carbide in 1936 as unit foreman and then worked in successive positions in research at Mellon Institute. He rejoined Carbide as product manager in the fine chemicals department.

Before taking a leave of absence last year to act as assistant administrator of the Business and Defense Services Administration, United States Department of Commerce, Mr. Field had served Carbide as assistant manager of the Fine Chemicals Department.

Mr. Field has been a member of the A.I.Ch.E. since 1946.

Hooker Electrochemical Co. announces **Gerald L. Glespen** as sales analyst in the Niagara Falls, N. Y., office.

Mr. Glespen comes to Hooker from a position as assistant to the manager of the refinery chemicals department of American Cyanamid. He received his B.S. in chemical engineering from Newark College of Engineering in 1936.

R. B. Porter, graduate in chemical engineering from M.I.T., has recently been appointed as a technical service representative for the Paper Chemicals Division of the Nopco Chemical Company.

Mr. Porter will spend most of his time in the field studying manufacturers' problems and demonstrating the use of Nopco products.

Fred Raible takes over as manager of the West Hartford, Conn., office of the Trane Company.

Mr. Raible joined Trane in 1948 in the company's student engineering class. He had received his B.S. in chemical engineering from the University of Rochester.

PEOPLE

George Granger Brown, Edward DeMille Campbell University professor of chemical engineering and Dean of the University of Michigan College of Engineering, was recently chosen to deliver the 30th annual Henry Russel Lecture this spring. He is the first engineer to receive this honor.

The lectureship, endowed by Henry Russel, is regarded as the University of Michigan's highest professional recognition of academic and scientific competence.

Dr. Brown began his career in 1917 with the Aluminum Company of America after graduation from New York University. After two years in the Chemical Warfare Service he joined the Union Special Machine Company in Chicago as production manager.

In 1920, Dr. Brown joined the faculty of the University of Michigan as instructor and obtained his Ph.D. from this school in 1924. This same year he earned the degree of chemical engineer from New York University.

In 1944, Dr. Brown served as president of the A.I.Ch.E. and has been chairman of the Institute's education committee since 1948. He received the 1939 William H. Walker Award from the Institute.

Besides his several other honors, Dr. Brown is author and co-author of over 150 technical papers in his field. He has served, too, as director of the U. S. Atomic Energy Commission's Division of Engineering with responsibility for the chemical engineering phases of the Commission's reactor development program.

George F. Jenkins, chairman of the public relations committee of the A.I. Ch.E., will take up residence at Brookhaven National Laboratory, Long Island, N. Y., for six months to a year on a special reactor study.

Nevin K. Hiester assumes duties as manager of the chemical and metallurgical engineering section of the Stanford Research Institute.

Dr. Hiester, with SRI since 1949, has led research programs on ion exchange, food processing, industrial hygiene, fluid control and heat transfer.

Neal R. Amundson, head of chemical engineering at the University of Minnesota, is spending this school year at Cambridge University, England, as a Fulbright scholar in the departments of chemical engineering and mathematics

A. R. Powell advances from associate manager to acting manager of the

Arthur Linz has resigned his position as vice president of Climax Molyb-

PEOPLE

Kenneth E. Bell, a vice-president of the A. C. Lawrence Leather Company, Peabody, Mass., has retired after 31 years of service.

Dr. Bell was graduated in 1917 from M.I.T. and joined the Lawrence company in 1923. He had been responsible for all research and technical work since 1931 and a vice-president since 1945.

Dr. Bell has been an expert consultant to the office of Quartermaster General in Washington, a member of the Research Laboratory Committee of the Tanners' Council, and a Director of New England Council. He is, at present, on the Executive Committee and a Trustee of the Research Foundation of Lowell Technological Institute and Chairman of the Advisory Committee of the School of Leather Engineering of the Institute.

During his membership since 1943 in the A.I.Ch.E., Dr. Bell has served on the committee of the Chemical Engineering Catalog and was chairman of that committee from 1951 to 1953. He is a founder of the much-talked-about Ichthyologists Club of Boston and has served on several committees of the Boston local section meetings.

Walter H. Rupp has been appointed technical advisor to M. W. Mayer, director of the Esso Engineering Economics Division of Standard Oil Development Company.

Mr. Rupp joined the Development company in 1936. He is a member and organizer of the New Jersey Section of the A.I.Ch.E.

Bryce L. Rhodes joins the International Minerals & Chemicals Corporation's Phosphate Chemicals Division as development manager.

He will be responsible for the development and promotion of new products and by-products closely related to the operations of the Phosphate Chemicals Division.

Mr. Rhodes comes to International from the position of vice-president of Synthron, Inc., of Rhode Island.

Clyde B. Myers has been named manager of research and development in the calcium and silicate section of the Silicate, Detergent, Calcium Division of Diamond Alkali Company.

Harry G. Foden joins the staff of Arthur D. Little, Inc., as chemical engineer in the company's Process Engineering Group.

A. R. Powell advances from associate manager to acting manager of the central Research Department of Koppers Company, Inc.

Dr. Powell, a leading scientist in coal chemical technology, will coordinate research activities of Kopper's six operating divisions as well as have responsibility for company-sponsored fellowships in several national research institutions and universities.

Industrial Rayon Corporation announces the appointment of **Desmond L. Farrell** as production superintendent of the nylon staple fiber plant at Covington, Va.

Harold G. Place joins the Dupont company as an engineer in the Victoria Plant Technical Section.

Mr. Place was secretary-treasurer of the A.I.Ch.E. student chapter before his graduation in chemical engineering from Texas A&M.

James M. Young, III, has joined the process study group of Hooker Electrochemical Company at Niagara Falls, N. Y. as chemical engineer. **Charles H. Carr** will work with the pilot plant group in the research and development department of the company.

Herman N. Woebcke takes over as chief engineer of the Mobay Chemical Company.

Arthur Linz has resigned his position as vice president of Climax Molybdenum Co. to open his own offices in New York as technical consultant.

Mr. Linz obtained his B.Sc. from Columbia Univresity in 1919 after having already acquired experience in the field as chemist in the laboratory and works of the Standard Aniline Products Co. In 1928 he received the equivalent of a master's degree from Polytechnical Institute in Zurich.

Up to 1924, Mr. Linz served successively as researcher in the classification and licensing of chemical patents and then as vice president with the Ore & Chemical Corp. During the next 11 years he served in Europe for the Standard Varnish Works, and Toch Bros., Inc., of New York and Chicago as technical director of European activities including work on natural and synthetic pigments, industrial and general paints, varnishes and lacquers. He also worked on special products such as insulating and water-proofing compounds.

Mr. Linz is inventor and patentee of molybdic oxide briquettes, the present form of calcium molybdate, molybdenum silicide and many of the present methods of operation in this field of manufacture.

In his new endeavor as consultant, Mr. Linz will embrace all fields of his experience.

Robert S. Nelson assumes duties of production superintendent of the Inorganic Chemicals Division plant of the Monsanto Chemical Company in Kearny, N. J.

Mr. Nelson joined Monsanto in 1946 with a B.S. degree in chemical engineering from the University of Iowa.

Phosphate Chemicals Division of International Minerals & Chemical Corporation names four to new posts:

William Bellano as production manager of the division; **Neil B. O'Donnell** as assistant manager of production; **Robert V. Safford** as assistant manager of engineering and maintenance and **James F. Roe** as superintendent of the Division's Bonnie, Fla. plant.

Albert G. Laverty is added to staff of the Esso Laboratories of the Standard Oil Development Company.

G. R. Shockley joins Olin Mathieson Chemical Corporation as manager of chemical process development in the research department. **Emil Czapek** takes over as manager of cellulose and colloid chemistry in the company.

Both men assume duties in the New Haven, Conn., office.

PEOPLE

With the establishment of two new major divisions Standard Oil Development Company announces appointments of **C. Wesley Tyson** to head the Petroleum Development Division and **Harold W. Scheeline** to direct the Chemicals Development Division.

Homer Z. Martin will direct the Process Division with **Burton C. Belden** as associate director of this unit. **Stanley E. Jaros** will take over as assistant director of the Chemicals Development Division.

Hercules Powder Company's Naval Stores Department has appointed **Arthur Langmeier** to the position of assistant general manager of Naval Stores in charge of production and development.

At the same time **G. Fred Hogg** takes over as assistant general manager in charge of sales and **Donald H. Sheffield** as manager of the Oxychemicals Division.

A. D. Green has been appointed to one of the newly created posts of deputy coordinator for the Standard Oil Development Company.

Mr. Green will work as deputy to Dr. C. O. Tongberg in chemical research and process research on lubes and specialty products.

At a recent meeting of the Engineering Division of the Technical Association of Pulp and Paper Industries in Philadelphia three members of the department of chemical engineering at the University of Maine received appointments:

Professor Lyle C. Jenness takes over as chairman of the chemical engineering committee of the national association; **Professor Richard E. Durst** was named a member of the hydraulics committee, and **Professor Andrew J. Chase** was named a member of the chemical engineering committee and will be chairman of the sub-committee.

E. F. Jennings, Jr., moves from assistant manager to plant manager of the Hercules Powder Company's Parlin, New Jersey, plant.

Mr. Jennings joined Hercules in 1939 as research chemist. He succeeds William H. Morrison.

Whiting Research Laboratories of the Standard Oil Company (Indiana) has announced **James H. Black, Robert J. Toman, Donald E. Kennedy** and **Roy J. Eisenhauer** as recent additions to the staff.

Necrology

Chemical Engineering Progress recently was notified of the death of the following members:

John A. Crowley, manager of building and construction in the central engineering department of U. S. Rubber Co.

After his graduatoin in 1910 from Yale, Mr. Crowley spent several years in railroading before taking over supervision of development and construction of hundreds of chemical plants as chief draftsman. He joined Carbide & Carbon Chemicals Co. in 1936 as assistant engineer in design and construction.

Mr. Crowley has been a member of the A.I.Ch.E. since 1941. At that time he had just completed two years in Haifa, Palestine, as chief engineer in field engineering for the M. W. Kellogg Co. Before assuming managerial duties at U. S. Rubber, Mr. Crowley had held the position of engineer in the organic chemistry department of the Dupont company.

Philip S. Barnes retired recently from the Pfaudler Co., Rochester, N. Y.

Mr. Barnes joined the Pfaudler Co. in 1919 and served in the respective positions of sales engineer, eastern sales manager and finally as manager of sales for the chemical division.

Before beginning his career at Pfaudler, Mr. Barnes had served in the U.S.N.R.F. as Ensign working on helium development. His first position after graduation in 1913 with a B.S. in chemical engineering from M.I.T. was in analysis and research for the Avery Chemical Company in Lowell, Mass.

Dr. Edgar Eugene Randolph, 76, retired head of the Chemical Engineering department of North Carolina State College.

Dr. Randolph earned his A.B., A.M. and Ph.D. degrees from the University of North Carolina. In 1925 he organized and developed the chemical engineering department of North Carolina College of Agriculture and Engineering where he succeeded to the position of head of the department.

Throughout his career, Dr. Randolph had engaged in varied chemical engineering projects including work for the state of North Carolina on coal specifications for state institutions and state fuel purchases and as a consultant on the problems of manufacturing companies.

Dr. Randolph has been a member of the A.I.Ch.E. since 1929 and an honorary member since 1948.

CLASSIFIED SECTION

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Opportunity in progressive, growing research and development department of eastern seaboard chemicals manufacturer. Prerequisites: degree in chemical engineering, about five to ten years of industrial experience preferably in process design, in pilot-plant development, in technical and process evaluation, and in cost estimation. Applicant must possess pleasant personality and be capable of representing the company when in charge of special assignments.

Send complete résumé, a recent photograph, and expected salary to Box 4-1.

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Chemical engineer to manage newly organized process development and pilot-plant section of expanding research laboratory in suburban Buffalo. Vegetable oil refining, chemical modification of oils, edible oils, synthetic resins, mixed fertilizers, etc. Contact with plants. Administrative talent and eight to ten years of broad engineering experience in process work, plant design, and scale-up needed.

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. . . to provide consulting service in solving complex technical problems in engineering, design, production, and research. Applicants should have broad basic experience and the desire to specialize in one of the following fields:

Heat Transfer, diffusional operations (particularly drying and crystallization), and solids processes including size reduction, separation, and fine particles technology.

DEVELOPMENT ENGINEERS

. . . to provide technical assistance to operating plants and laboratories in various fields of chemical engineering. Experience should include two to five years in one or more of the following:

Process or equipment development, trouble shooting, applications, research, or economic evaluations.

SPECIALISTS IN APPLIED CHEMICAL KINETICS

. . . to provide consulting service in the application of thermodynamics and reaction kinetics to the evaluation of new chemical processes. Duties will include:

Preparing flow sheets and estimating investments and operating costs; making studies developing the new processes for long-range planning, and for improving the economics and capacity of existing plants.

Please send complete résumé, including details of education and experience to:
Mr. J. C. Costello, Jr.
Personnel Section, Engineering Dept.

E. I. du Pont de Nemours & Co., Inc. Wilmington 98, Delaware

CHEMICAL ENGINEERS

Pioneer petroleum engineering firm has immediate permanent openings for qualified engineers in technical service on licensed units in many different refineries and for start-up operation on new units. Opportunities provided for domestic and foreign travel. Technical services or operating experience in petroleum refinery or chemical plant necessary.

Offices are in Philadelphia near transportation to desirable residential suburbs.

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CHEMICAL ENGINEER—Five to ten years' experience. Must be capable of undertaking the development of new processes incorporating the various unit operations. Previous experience in phosphate fertilizers desirable but not necessary if applicant commands practical knowledge of unit operation. Southwestern United States. Send complete résumé and salary requirements. Box 3-1

SITUATIONS WANTED

A.I.Ch.E. Members

PROJECT ENGINEER—P.E. Cost estimates and construction proposals prepared for selected processes in organics, fats, oils, detergents, and pharmaceuticals. Flowsheets and layouts. Consulting basis only. Northeast. Box 1-1.

SALES EXECUTIVE—CHEMICAL ENGINEER—Thirteen years' engineering, sales experience. B.Ch.E. Member A.C.S., A.I.Ch.E., wide contacts. Now Eastern district manager for heat exchanger manufacturer. Seeking executive sales opportunity preferably in New York area. Box 2-1.

CHEMICAL ENGINEER—Twenty-seven years' diversified experience with a major producer of organic chemicals. Experience entails production supervision, plant development, senior project engineer, engineering sales. Desire administrative or sales position with responsibilities. Small to medium-sized company. Box 5-1.

CHEMICAL ENGINEER—Four years' layout and engineering of petrochemicals, 3¼ years' pilot plant, 1½ years' plant engineering. Northeast preferred. Box 6-1.

DEVELOPMENT SUPERVISOR — M. Ch. E. Ten years with leading dry food manfacturer; recently as pilot-plant supervisor. Experience includes process and product development, design, patent work and economic studies. Desire more responsible position. Age 32. Married. Box 7-1.

INSTRUMENTATION—B.S.Ch.E. 1952. Desire placement in engineering position primarily concerned with chemical process instrumentation. Limited experience. Geographical location optional. Have recently completed military service requirements. Married. Age 24. Box 8-1.

CHEMICAL ENGINEER—Ph.D. Experience in process design and economic evaluation. Strong on petroleum refining, ammonia, and petrochemicals. Proficiency in heat transfer, distillation, absorption, mathematics, and statistics. Desire position as process design or development engineer. Box 9-1.

CHEMICAL ENGINEER—B.S. 1950. Age 27. Four years' process equipment development, production, quality control. Desire responsible position in process or process equipment development involving liquid extraction or distillation. Process high mechanical aptitude. Box 10-1.

CHEMICAL ENGINEER—B.S.Ch.E. 1950. 1¼ years' development and production of organics. Three years' pilot-plant development, construction and operations. Three years' chemical plant experience prior to 1950. Desire job in development or production in organics in Midwest. Box 11-1.

PRODUCTION CHEMICAL ENGINEER — Three years' production supervision experience including responsible charge of manufacturing operations; one year's applied research; safety conscious. B.S. plus graduate work, Tau Beta Pi, 31. Desire responsible, challenging position in production or development. Box 12-1.

CHEMICAL ENGINEER—B.S., 1941. Thirteen years' diversified experience. Last seven in development in organic pigments, rubber chemicals. Laboratory, pilot plant and plant background. Desire stimulating, responsible development position with future. Age 35, married, family. East preferred. Box 13-1.

RESEARCH AND DEVELOPMENT ENGINEER—M.S.Ch.E. 1949. Five years' experience in process development and project engineering; large scale experimentation; technical report writing. Excellent theoretical background. Publications. Age 26, family, veteran. Box 14-1.

DIRECTOR OF ENGINEERING—Completion of present work necessitates relocation. Experienced in phosphates, plastics, and nitric acid. Desire managerial position in production or engineering. Immediate availability. M.S. in Ch.E., age 36, married. Box 15-1.

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Advertisements in the Classified Section of Chemical Engineering Progress are payable in advance at 15c a word, with a minimum of four lines accepted. Box number counts as two words. Advertisements average about six words a line. Members of the American Institute of Chemical Engineers in good standing are allowed one six-line Situation Wanted insertion (about 36 words) free of charge a year. Members may enter more than one insertion at half rates. Prospective employers and employees in using the Classified Section of Chemical Engineering Progress agree that all communications will be acknowledged; the service is made available on that condition. Boxed advertisements are available at $15 a column inch. Size of type may be specified by advertiser. Answers to advertisements should be addressed to the box number, Classified Section, Chemical Engineering Progress, 25 West 45th Street, New York 36, N. Y. Telephone COlumbus 5-7330. Advertisements for this section should be in the editorial offices the 15th of the month preceding publication.

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news and notes

Year End in the Institute brings with it much reportable activity . . . New committees are appointed, committee reports are studied, & council takes action on past activities & future recommendations.

During the year we will mention activities of various committees & tell something of their past accomplishments & future plans, & so no attempts will be made to cover all the events in this January News & Notes.

In the September News & Notes we reported the nominating procedures & the problem of publicity for candidates . . . in October Council resolved the difficulty by an addition to the By-laws which stipulates that the nominating committee shall render its slate of officers & directors 18 weeks prior to the Annual Meeting . . . & the slate is to be publicized in Chemical Engineering Progress.

The foregoing procedure Council hopes will enable local sections to see the choices of the nominating committee before filing their petitions for favorite sons. Overlapping of petitions & nominating-committee choices this year caused some confusion, & the lateness of the deadlines made proper publicity a problem.

As the Annual Meeting next year will be held the last week in November, the nominating committee will have its report ready no later than the week of July 25th.

The A.I.Ch.E. is going to cooperate with the American Military Engineers in a meeting on Selective Service & manpower requirements this February 10 & 11 . . . Cooperation will be through Engineers' Joint Council along with the other major engineering societies.

A National Meeting was approved by Council to be held in Baltimore, Md., September 15-18, 1957. The Lord Baltimore Hotel will be headquarters.

A switch was made in the schedule for the White Sulphur Springs, W. Va., meeting . . . instead of being held in 1958 it is now scheduled for March 10-13, 1957, with the Central Virginia Section as host.

Council recently worked on committee appointments & chairmen. New to the list mentioned in November are R. C. Kintner as chairman of Chemical Engineering Education Projects Committee; J. C. Elgin as chairman of the Symbols & Nomenclature Committee; & G. E. Holbrook as chairman of the Publications Committee.

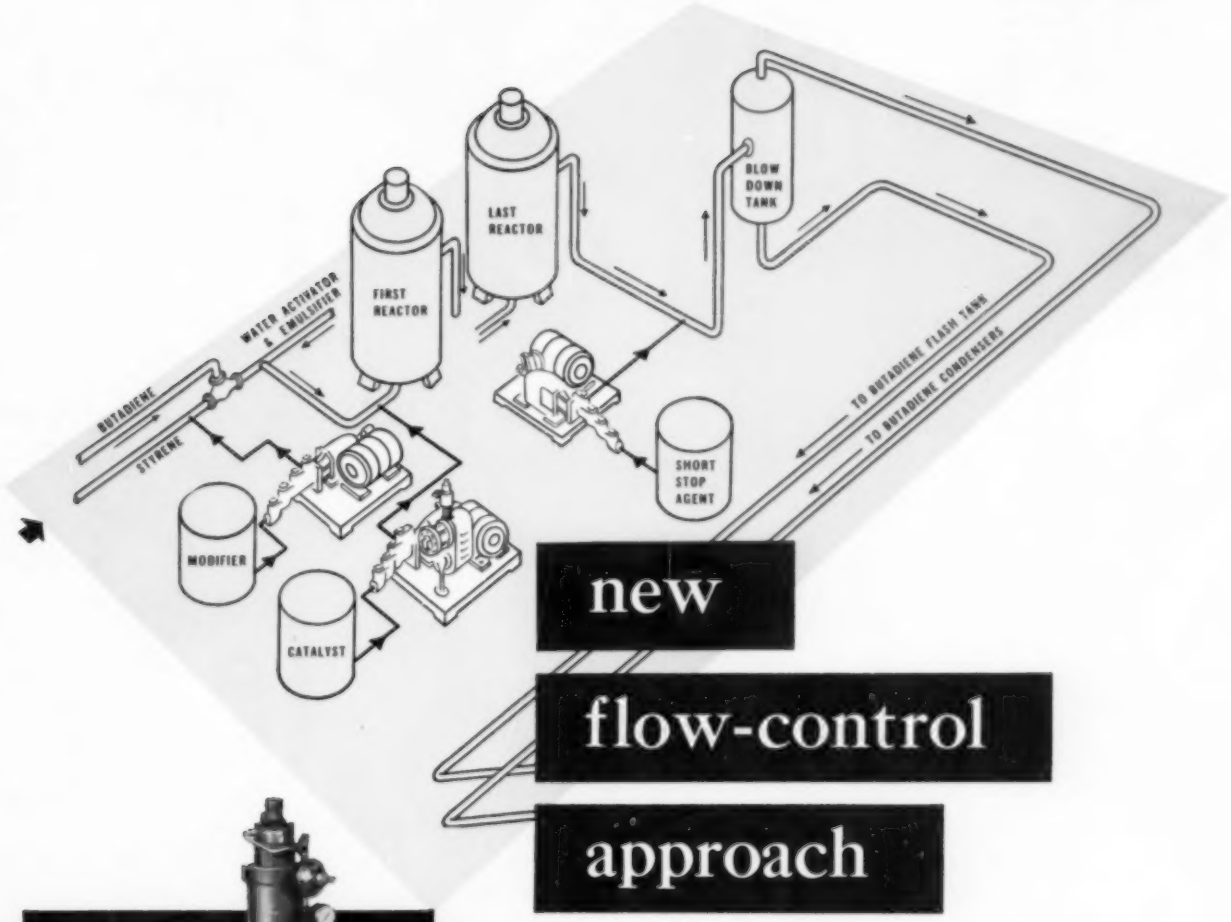
Council also accepted for approval a budget for 1955. This shows a net projected loss of some $25,000 owing to the new Journal, which will be offered for the first time in 1955. Council also spent considerable time dealing with the general problem of financing Institute publications & advised the Publications Committee that it was not unalterably opposed to asking industry's help in supporting the new Journal if it becomes necessary. Council also instructed the Publications Committee to work out a plan for such support, to be submitted to Council for consideration.

An extremely important move of Council was the appointment of a Standards Committee for the creation of standards in the chemical industry & for cooperation with the American Standards Association. J. C. Lawrence, Sr., former director of the A.I.Ch.E., was nominated as its first chairman.

New local sections were voted for Dallas, Texas, & for the Savannah River area on the recommendation of S. L. Lopata, chairman of the Institute Sections Committee.

Nuclear Engineering meeting is on its way for December 12-17, 1955, in Cleveland. The conference itself will be under the sponsorship of Engineers' Joint Council plus additional societies such as the American Nuclear Society, the American Chemical Society, & the American Institute of Physics. The A.I.Ch.E. will at this time also hold its second nuclear exposition. The first was held at Ann Arbor last June & tentative plans were to hold another one in Detroit this year. Engineers' Joint Council program committee however agreed to the Institute's holding its exposition at the time E.J.C. holds its conference. More news about this in later reports & in C.E.P.

F.J.V.A.



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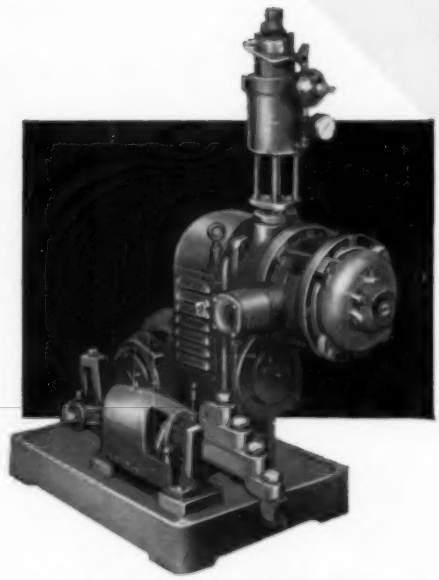

Motor-driven controlled volume pump, with air-controlled variable drive, which adjusts pumping speed automatically to control rate of reaction.

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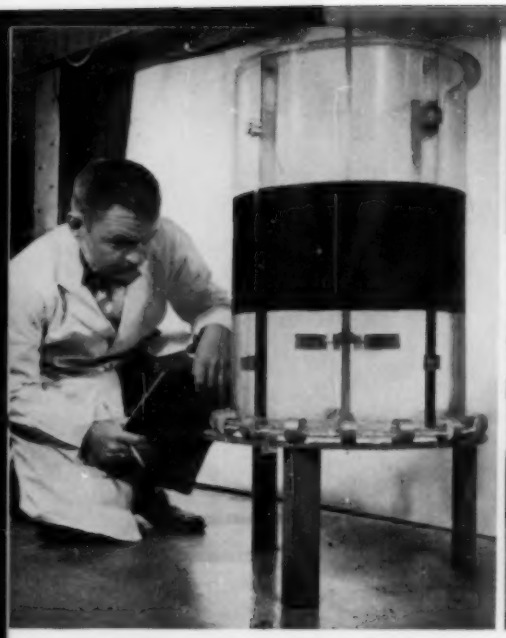

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It begins with the mixer impeller. The one you see here is a LIGHTNIN design chosen for high pumping capacity, or fluid flow.

Flow is what circulates the droplets (or gas bubbles) in a controllable pattern, assuring intimate contact throughout the fluid mass.

You need *fluid shear*, too. Shear breaks the big droplets (or bubbles) into millions of pinpoint ones, tremendously increasing interfacial area.

For optimum results, you need *flow* and *shear* in just-right balance. These are basic, though many other variables may affect the final answer.

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He can quickly find the optimum speed and diameter that will give you the results you want in least time—and with least horsepower. There's no guesswork.

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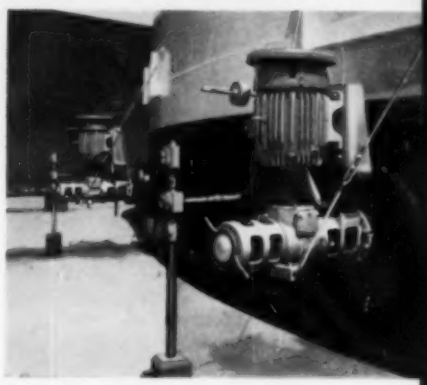
ANTIBIOTIC FERMENTATION is big example of gas-liquid contacting operation. This one consists of six 200-HP LIGHTNIN Mixers, with 39-foot shafts, on six 24,000-gallon tanks.



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